Water Power

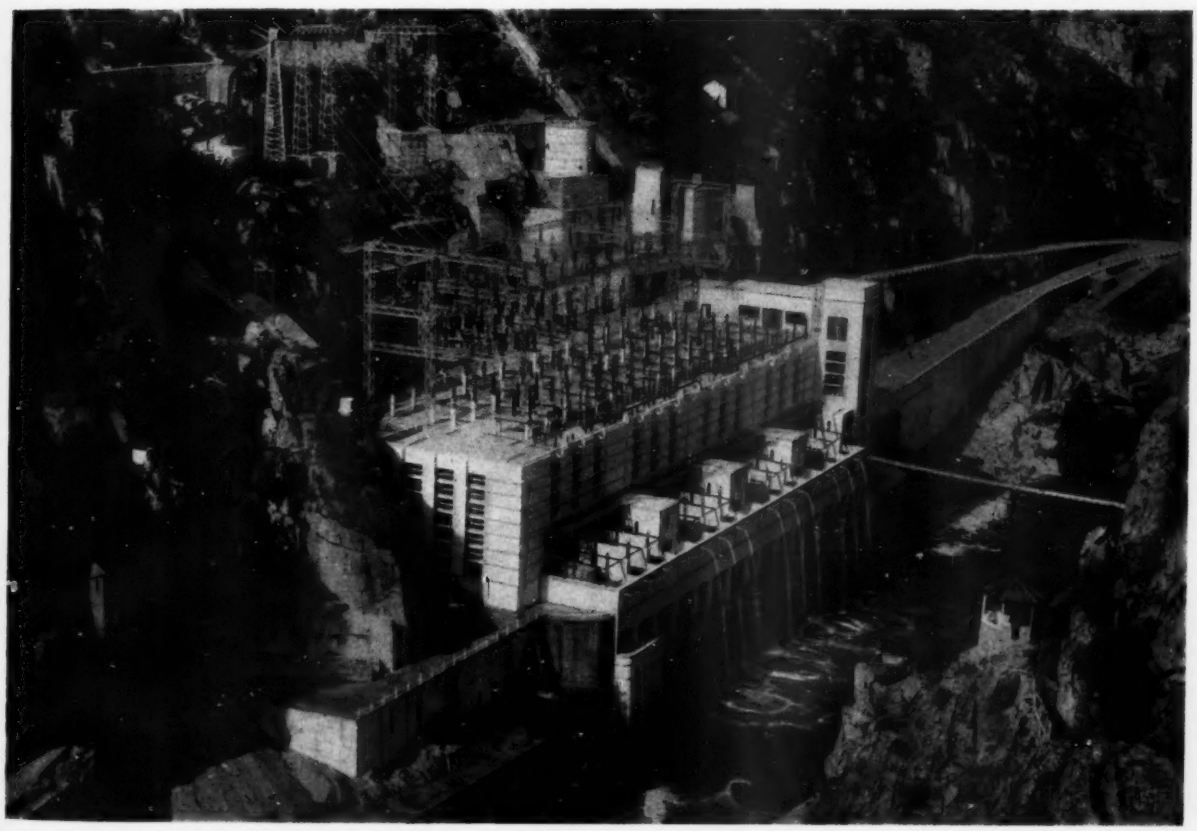
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 NOVEMBER 1958

TEXAS TECHNOLOGICAL
NOV 12 1958
COLLEGE

SAN ESTEBAN

is the largest power station in Spain. This hydro-electric station is equipped with four 75,000 kVA a.c. generators, together with transformers and switchgear, supplied by Metropolitan-Vickers.



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ELECTRICAL CO LTD · TRAFFORD PARK · MANCHESTER, 17

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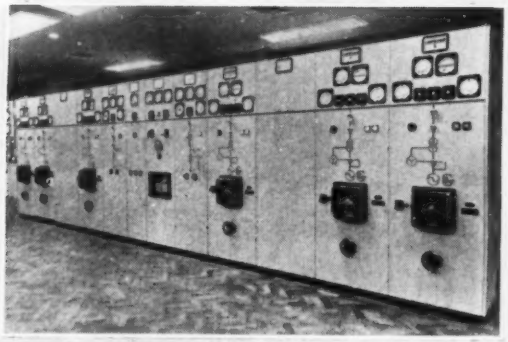
LEADING ELECTRICAL PROGRESS

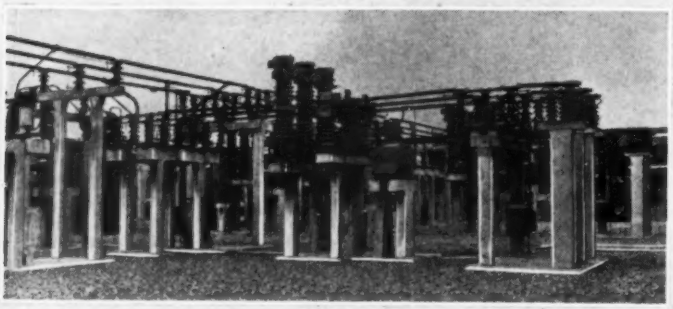
ROLLS-ROYCE LTD. DERBY. AERO ENGINE ALTITUDE TEST PLANT

WITH SWITCHGEAR SUPPLIED BY REYROLLE

The 33-kV 1000-MVA small-oil-volume switchgear and ancillary equipment controlling the supply to the six 22,000-H.P. compressor-motors was manufactured and installed by Reyrolle



Photographs by courtesy of Rolls Royce Ltd.
Consulting Engineers: McLellan and Partners in association with Messrs. Merz and McLellan



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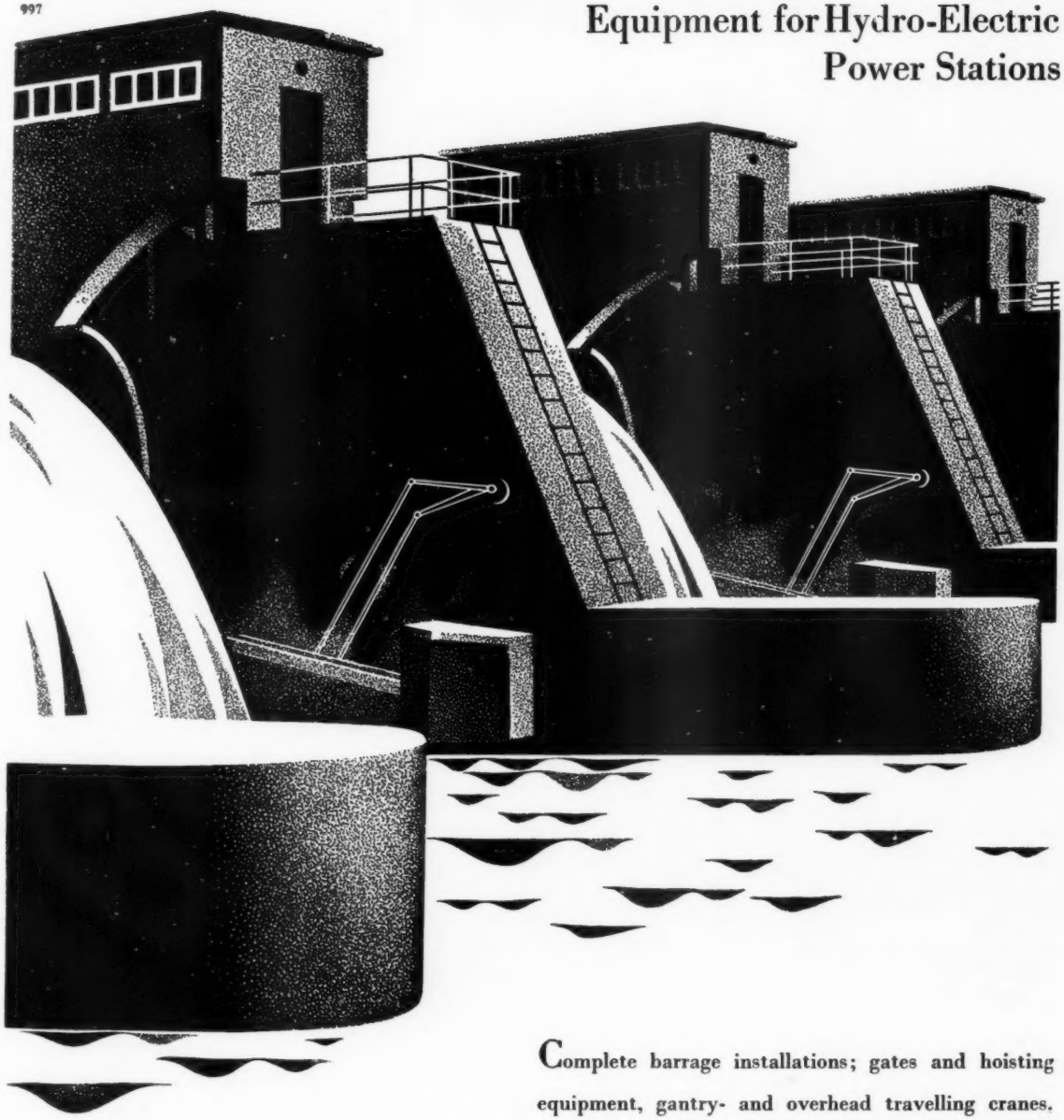
Equipment for Hydro-Electric Power Stations



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Louis de Roll, Ironworks Ltd.
Works at Gerlafingen, Klus, Choindez, Rondez, Olten, Berne (Switzerland)

Complete barrage installations; gates and hoisting equipment, gantry- and overhead travelling cranes, trash screen cleaning machinery; sluice gates; control valves for high pressure conduits; automatic safety organs for pipe lines; discharge regulating valves, rotary valves with rotary-piston servomotors, needle valves, butterfly valves, high pressure fittings, piping systems for oil and cooling water plant; funicular and aerial cableways for passenger and goods transport; building machinery for dam-building work.

POST INSULATORS for the Hirakud Dam project

S.P.P. Post Insulators were supplied for the 132kV. outdoor switchgear on the Hirakud Dam Project.

S.P.P. Post insulators have also been used on all the major hydro-electric projects in India, including the following:—

Damodar Valley Corporation
U.P. Government
Madras Government
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Travancore—
Cochin Government
Bombay Grid Scheme
Jog Falls Scheme
Machkund Scheme
North Calcutta Scheme
Pallivasal Scheme
Tungabhadra Scheme
Kunda, Madura, Mettur Dam, Moyar, Papanasam and many other substations on the Madras Grid.

STEATITE & PORCELAIN PRODUCTS LTD.

Stourport-on-Severn, Worcestershire. Telephone : Stourport 2271. Telegrams : Steatain, Stourport

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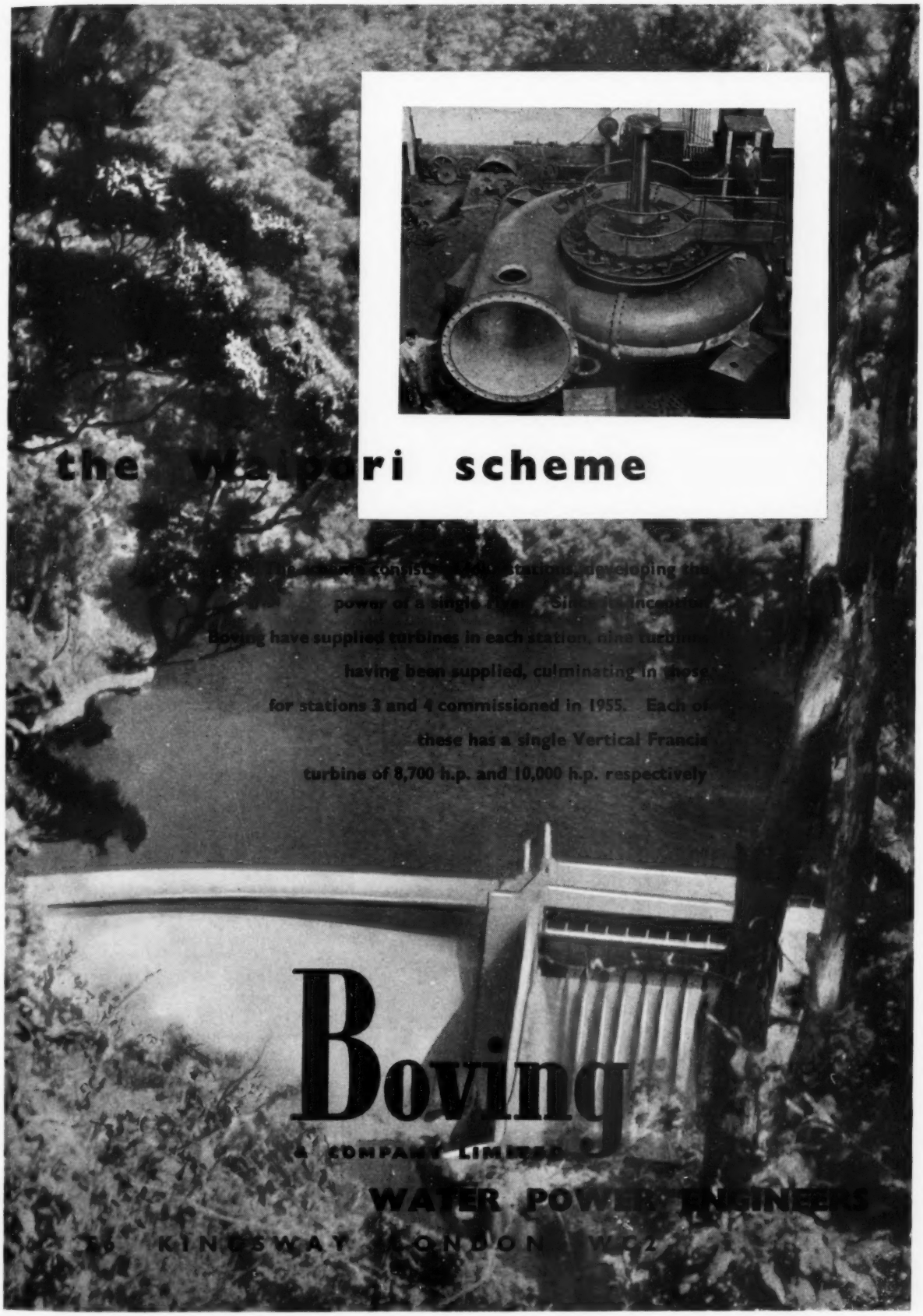
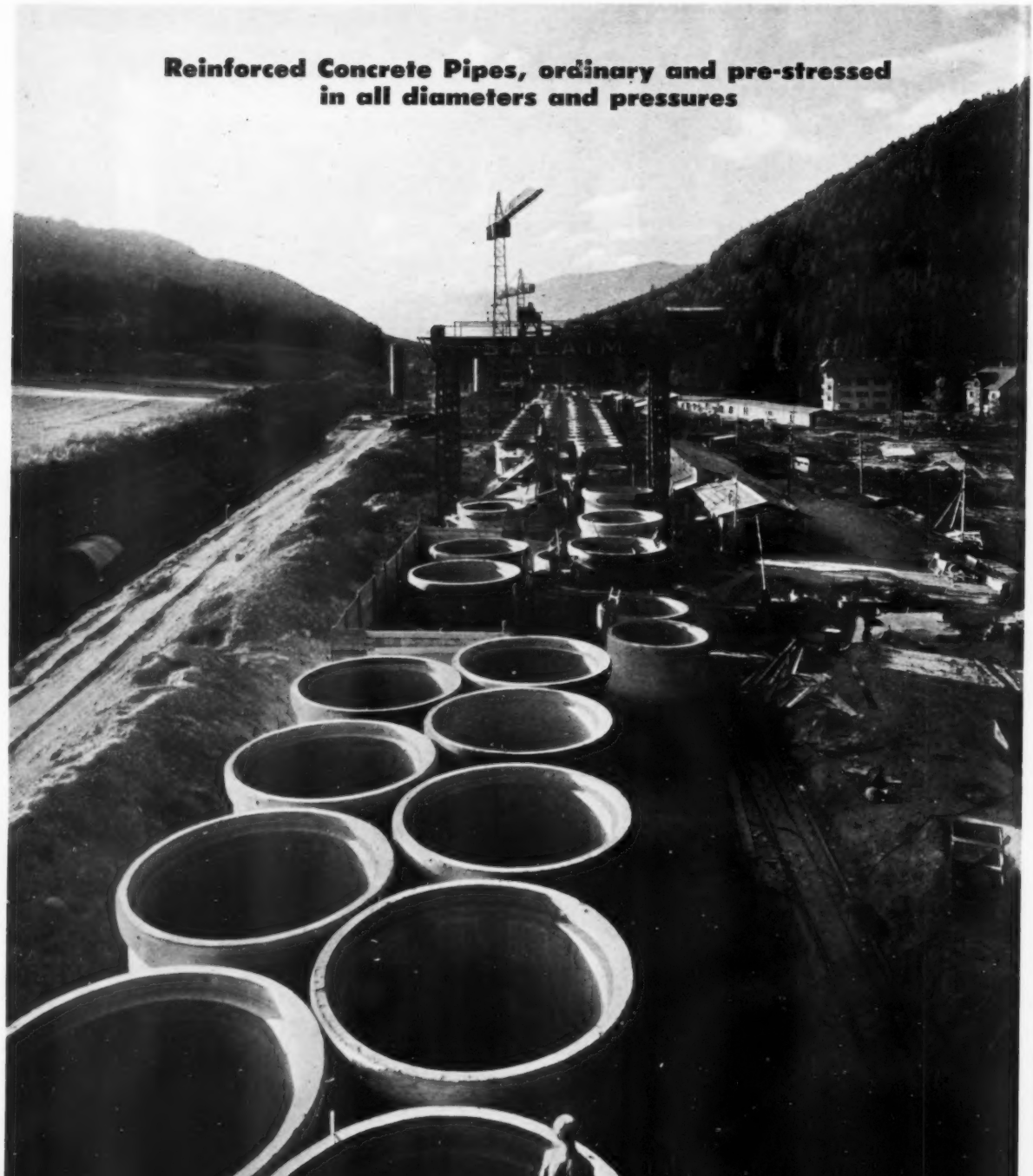

the Waipori scheme
Boving
& COMPANY LIMITED
WATER POWER ENGINEERS
56 KINGSWAY LONDON WC2

Reinforced Concrete Pipes, ordinary and pre-stressed in all diameters and pressures



Pre-stressed reinforced concrete pipe, diameter 3·30m. pressure 9 atm. Brunico hydro-electric power station, Italy. Soc. Montecatini

SACAIM

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The SCARPA & MAGNANO Co.
have been manufacturing since 1919:

- MINIMUM OIL CONTENT CIRCUIT BREAKERS
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  HIGH INTERRUPTING CAPACITY UP TO 4000 MVA
- HINGE AND ROTATING TYPE ISOLATORS

  PANTOGRAPH TYPE DISCONNECTING SWITCHES UP TO 220 KV
- CURRENT AND VOLTAGE METERING TRANSFORMERS
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- METAL-CLAD SWITCHGEAR FOR OUTDOOR AND INDOOR INSTALLATIONS
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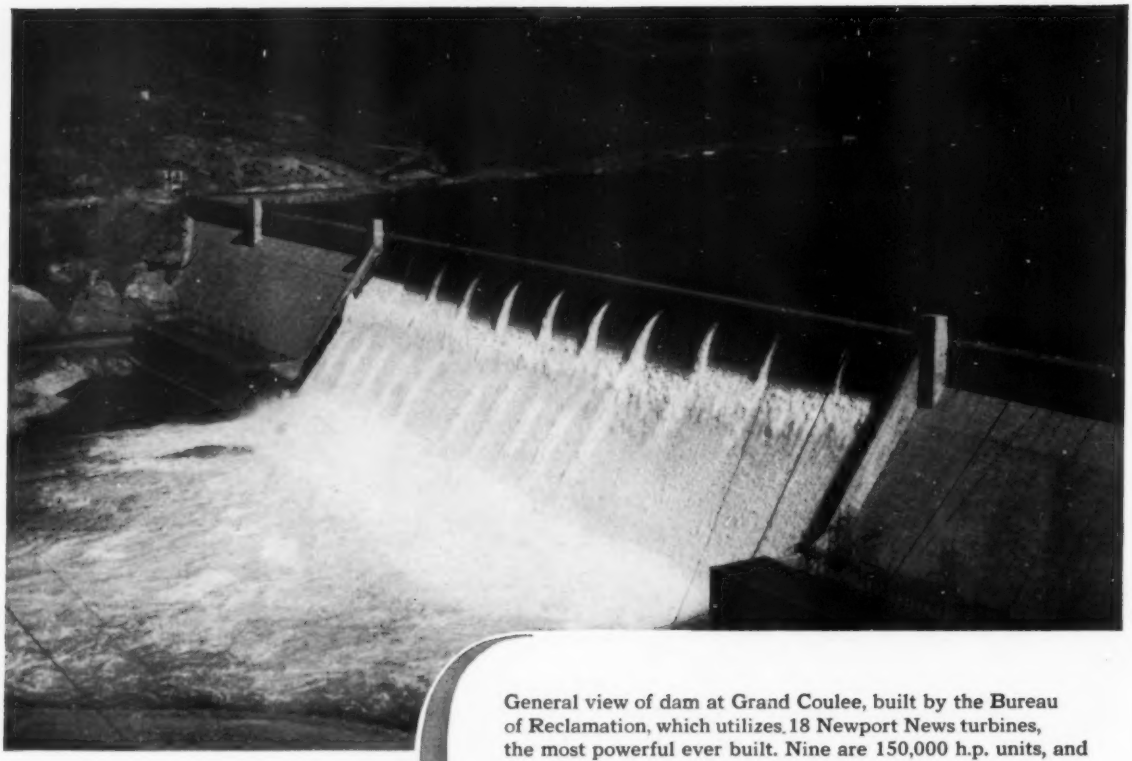
- POWER PLANTS AND SUBSTATION EQUIPMENTS
- UNIT SUBSTATIONS

SAVONA - ITALY



General view of dam at Grand Coulee, built by the Bureau of Reclamation, which utilizes 18 Newport News turbines, the most powerful ever built. Nine are 150,000 h.p. units, and the other nine are rated at 165,000 h.p. each.

Specialists . . . in building Water Power Equipment

Typical Users of Newport News Equipment

PLANT	LOCATION
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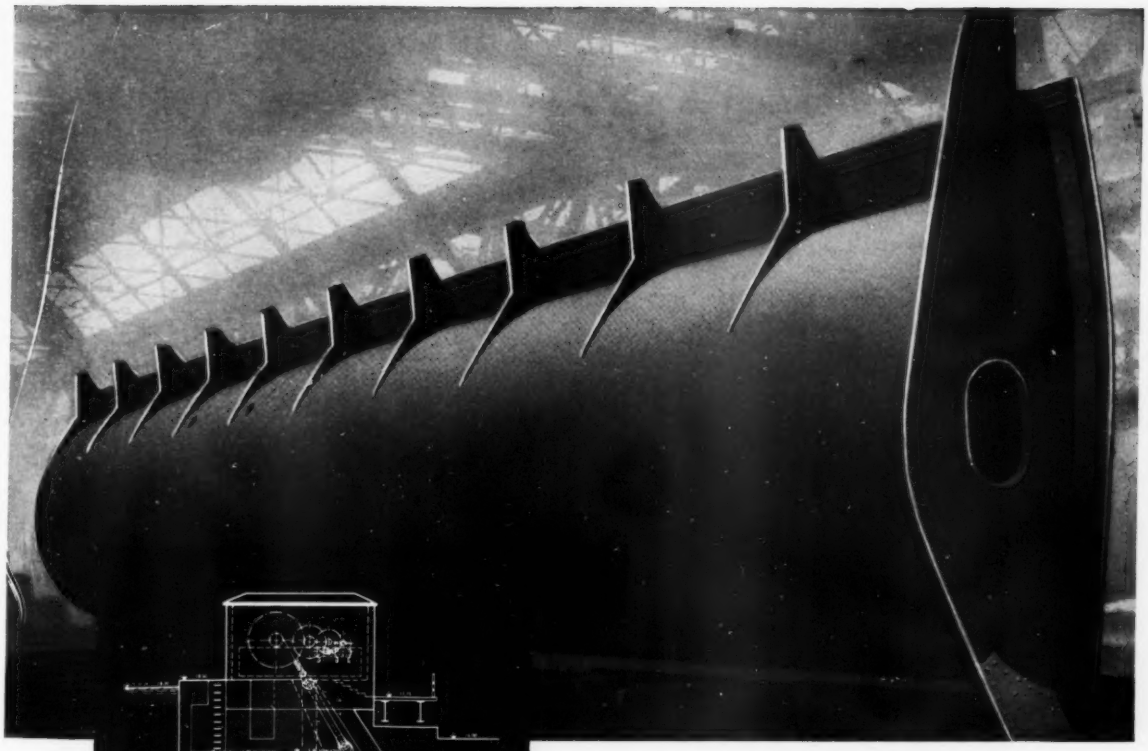
Buchanan	Texas
Caonillas	Puerto Rico
Chief Joseph	Washington
Clark Hill	South Carolina
Deer Lake	Newfoundland
Folsom	California
Fort Patrick Henry	Tennessee
Hiwassee	Tennessee
Hoover	Nevada
J. H. Kerr	Virginia
Jim Woodruff	Florida
Lower Salmon	Idaho
Norris	Tennessee
Rock Creek	California
Santee-Cooper	South Carolina
C. J. Strike	Idaho
Whitney	Texas
Wilson	Alabama

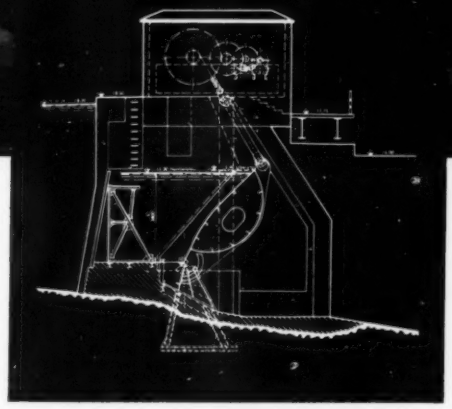
Turbines designed and built for the world's largest development at Grand Coulee... and for other hydroelectric installations in America and various parts of the world... bespeak the skill and facilities offered by Newport News.

This trained organization has filled hydroelectric turbine contracts with an aggregate rated output of 7,000,000 horsepower.

Other equipment designed and built by Newport News includes penstocks, pressure regulators, valves, pumps, gates and rack rakes. Upon request, a copy of our illustrated booklet entitled "WATER POWER EQUIPMENT" will be sent to you.

Newport News
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia





Above: Fishbelly flap, 24.5 m. width, 3.8 m. high, assembled in the workshop
Centre: Section of a weir with fishbelly flap
Below: Fishbelly flap, inside view

We construct and supply

Hydraulic steel structures for Weirs
River and sea locks
Valley storage dams
By-pass gates, Safety gates
High-pressure piping (penstocks)
Dock gates
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All hydraulic structures (including mechanical and electrical equipment) are supplied and erected ready for operation

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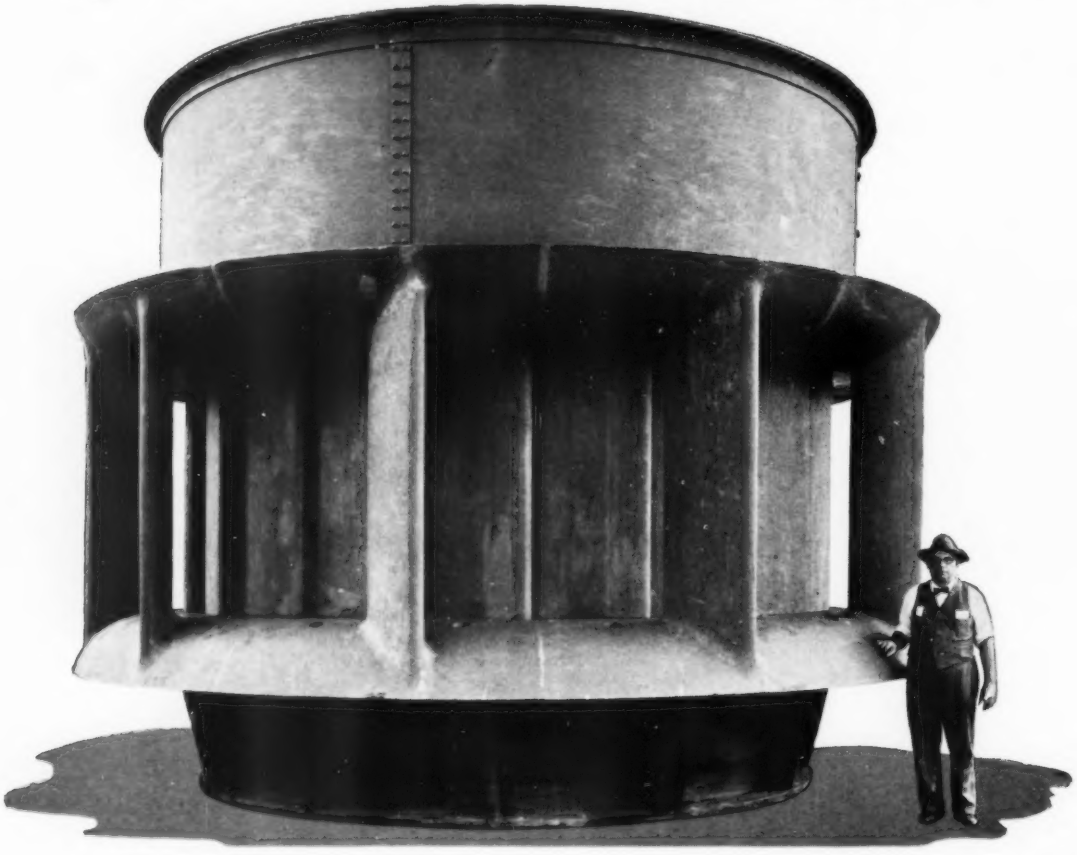
A LEFFEL TURBINE IS A TITAN OF QUALITY



The technical know-how, skilled personnel, use of the finest materials available, and rigid standards of quality control closely adhered to in the modern plant of The James Leffel & Company, enable Leffel to produce the ultimate in rugged, efficient turbines of the highest quality.

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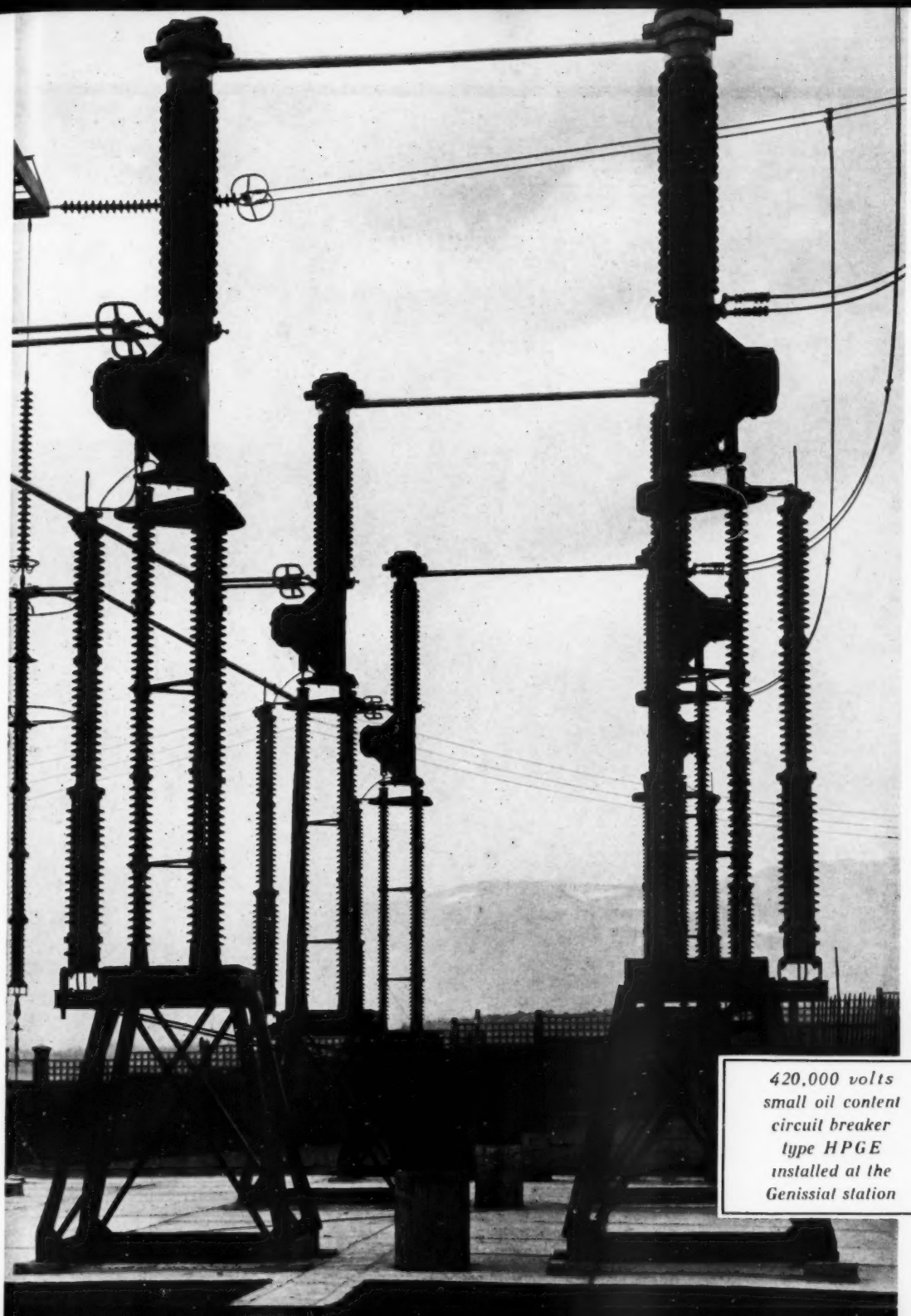

420,000 volts small oil content circuit breaker type HPGE installed at the Genissiat station

THE WHOLE OF APPARATUS UP TO 500,000 VOLTS

Ateliers de Constructions Electriques de

DELLE

DE LA COMPAGNIE GÉNÉRALE D'ELECTRICITÉ

25, CHEMIN DE CYPRIAN · VILLEURBANNE · FRANCE

9943

Penstocks, pressure shafts linings,
Substation steel structures
Gantry and overhead travelling cranes
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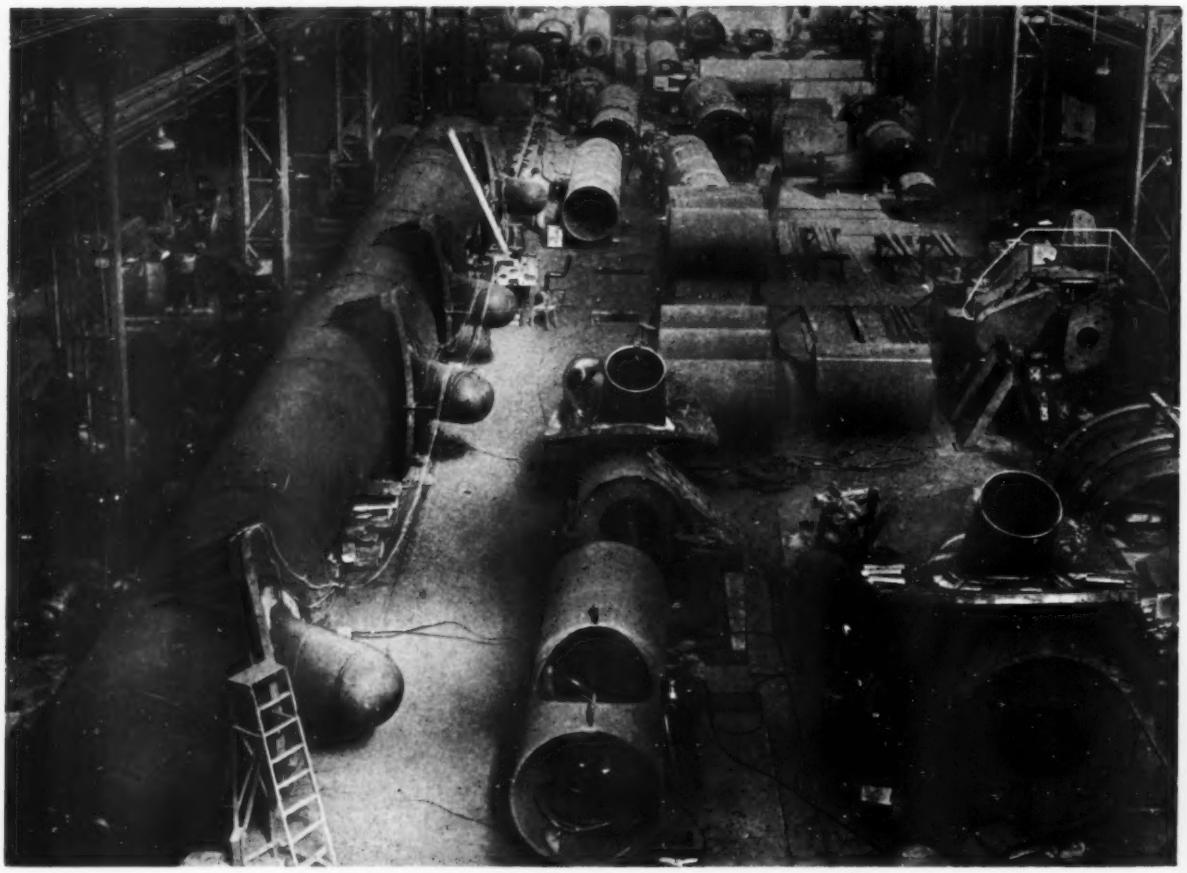
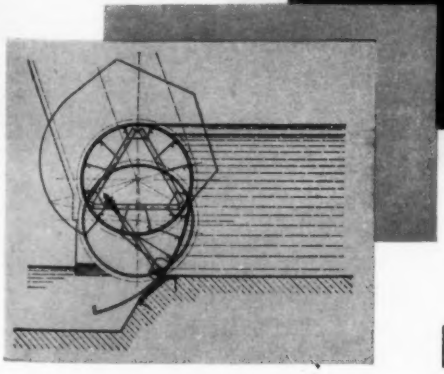


Downstream portion of the Grande Dixence Fionnay Power Station distribution pipe during tensometric shop tests. Max. wall thickness 52 mm., service pressure 96 at., test pressure 121 at.

GIOVANOLA Monthey - Switzerland

M·A·N



HYDRAULIC STRUCTURES

Roller gates particularly lend themselves for installation in rivers where sediment drift and ice prevail. For fine regulation of the water level gates can either be designed as submersible rollers or fitted with superposed flap.

Illustration shows roller weir in River Main near Randersacker, consisting of:

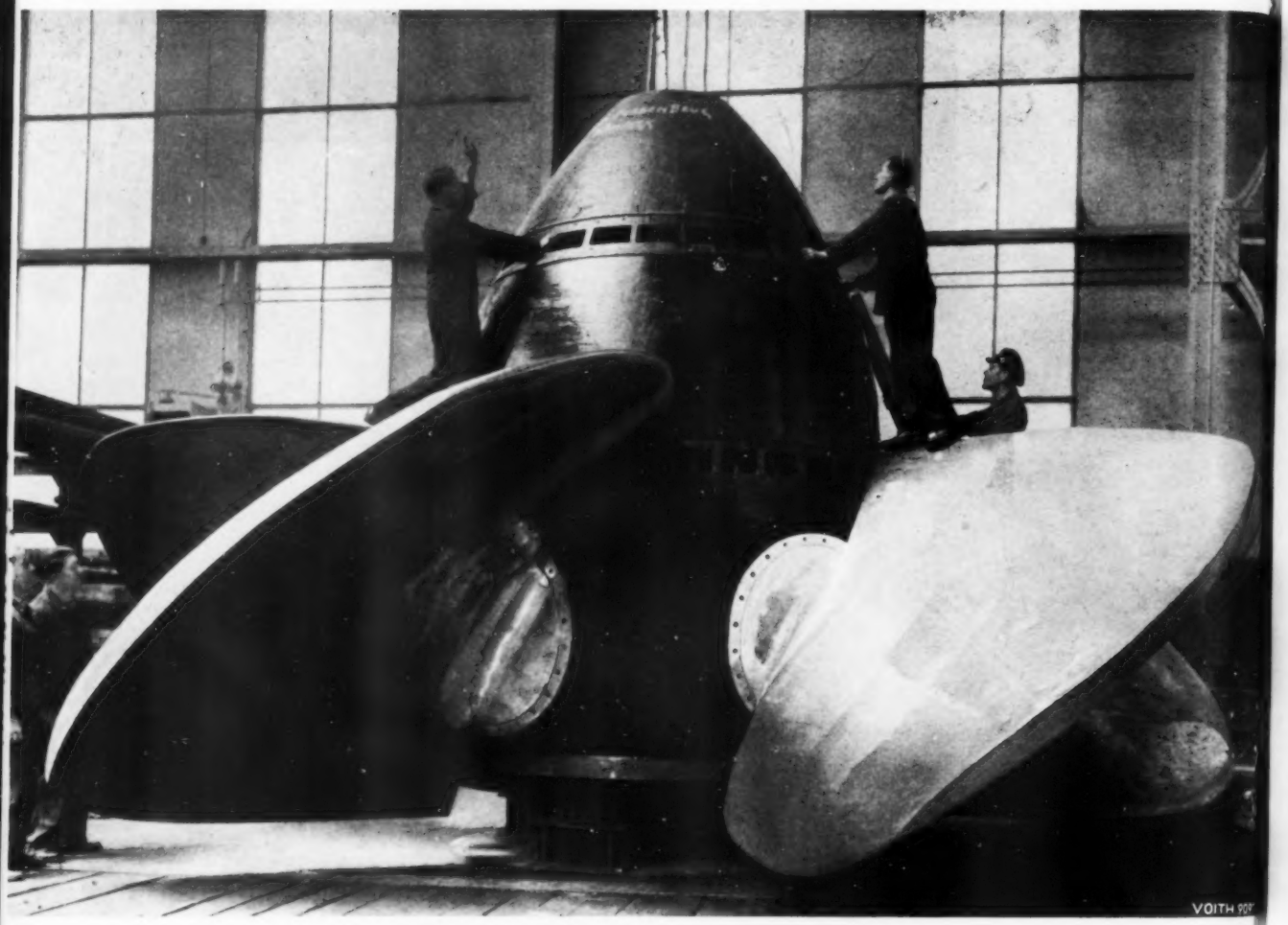
1 roller gate of 25.0 m clear width and 5.15 m water head,
(gate can be lowered by 1.3 m),

1 standard type roller gate of 25.0 m clear width and 5.15 m water head,

1 standard type roller gate of 30.0 m clear width and 5.15 m water head.

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) · REPRESENTATIVES IN ALL COUNTRIES

. . . . and on the Danube
another large run-of-river power station
is going into commercial operation

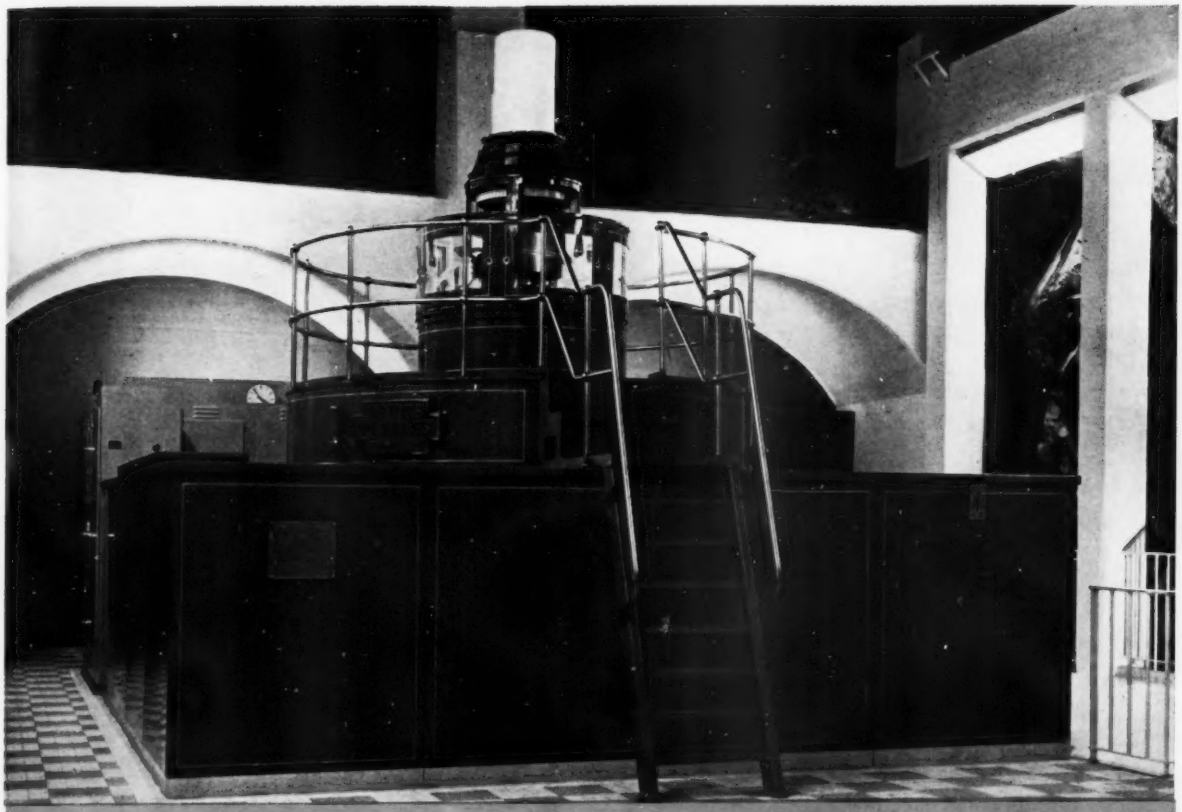


One of the five 24 ft. 4 in. Kaplan runners for the YBBS-PERSENBEUG Run-Of-River Power Station in the workshops of Voith-Heidenheim.

The first 4 Voith Kaplan turbines of this Power Station have already been commissioned, a fifth will shortly go into commercial operation. All five turbines, each developing 43,000 HP under a net head of 35 ft., are of Voith design and are built to plans and specifications of Voith-Heidenheim. Voith engineers have, for many years, taken a leading and pioneering part in the development and perfection of this turbine type, and numerous hydro-electric plants, ranging from small installations to largest projects, convincingly attest to the special features of Voith Kaplan turbines.

Two 91,300 HP Kaplan turbines for a maximum net head of 181 ft. are in manufacture in our workshops. They will equip a hydro-electric station in Brazil.

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY



Interior of St. Fillans underground power station of the North of Scotland Hydro-Electric Board showing a 21 MW 11 kV 600 r.p.m. vertical generator.

Hydro-Electric Plant

Bruce Peebles build large and small generators, horizontal and vertical types, designed to individual specifications, and transformers up to the largest sizes and highest voltages for hydro-electric power distribution.

25 MVA 11/132 kV transformer at St. Fillans power station

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THE NATURAL HISTORY OF WORLD CONSTRUCTION

Henderson again leads the field in Derrick Crane Design

Gruidae Hendersoniis (HENDERSON'S CRANE)

Discovered by John M. Henderson in Aberdeen, HENDERSON'S CRANES are native to Scotland but are found in great numbers in all parts of the world. Easily the finest specimens of a numerous species, their vigorous characteristics are unimpaired by climatic variations. Rising to great heights, they perform prodigies of strength and are noted for their stamina and longevity. Friends to man, they roost wherever he is breaking new ground and render great service by eradicating the common handling bug (*chaos extremens vulgaris*), frequent cause of industrial paralysis.

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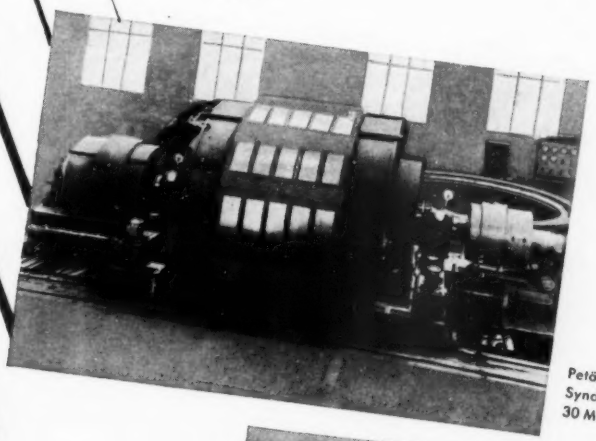
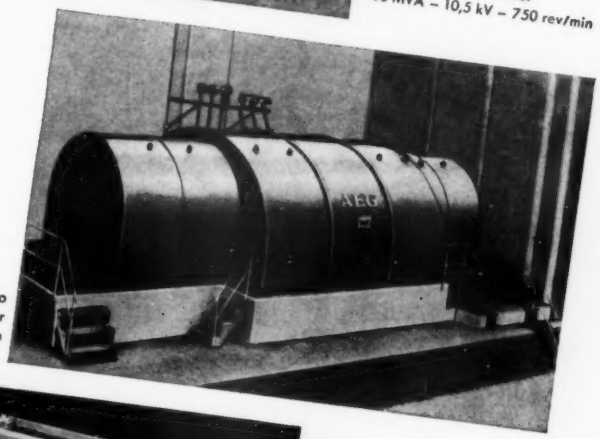
SYNCHRONOUS CONDENSERS

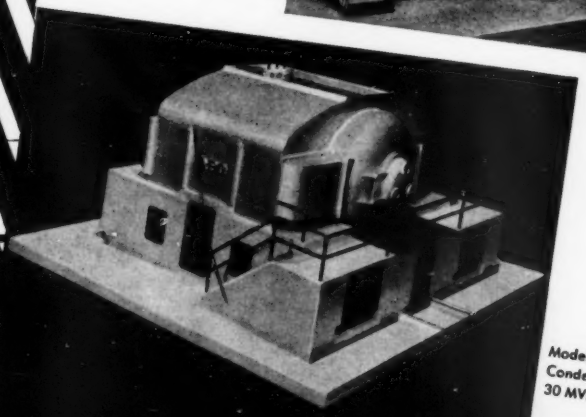
Economical operation of large grids and other distribution systems call for a compensation of the reactive component, i.e., improvement of the power factor.
Large synchronous condensers will best suit the purpose also under conditions of heavy line voltage fluctuations.
The AEG manufacturing programme covers all sizes of synchronous condensers for supply systems as well as for industrial application.



Petäjevesi, Finland
Synchronous Condenser
30 MVA – 10,5 kV – 750 rev/min



Norsk Hydro
Synchronous Condenser
36 MVA – 10,0 kV – 750 rev/min



Model of Synchronous
Condenser "Moron"
30 MVA – 13,2 kV – 1000 rev/min

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

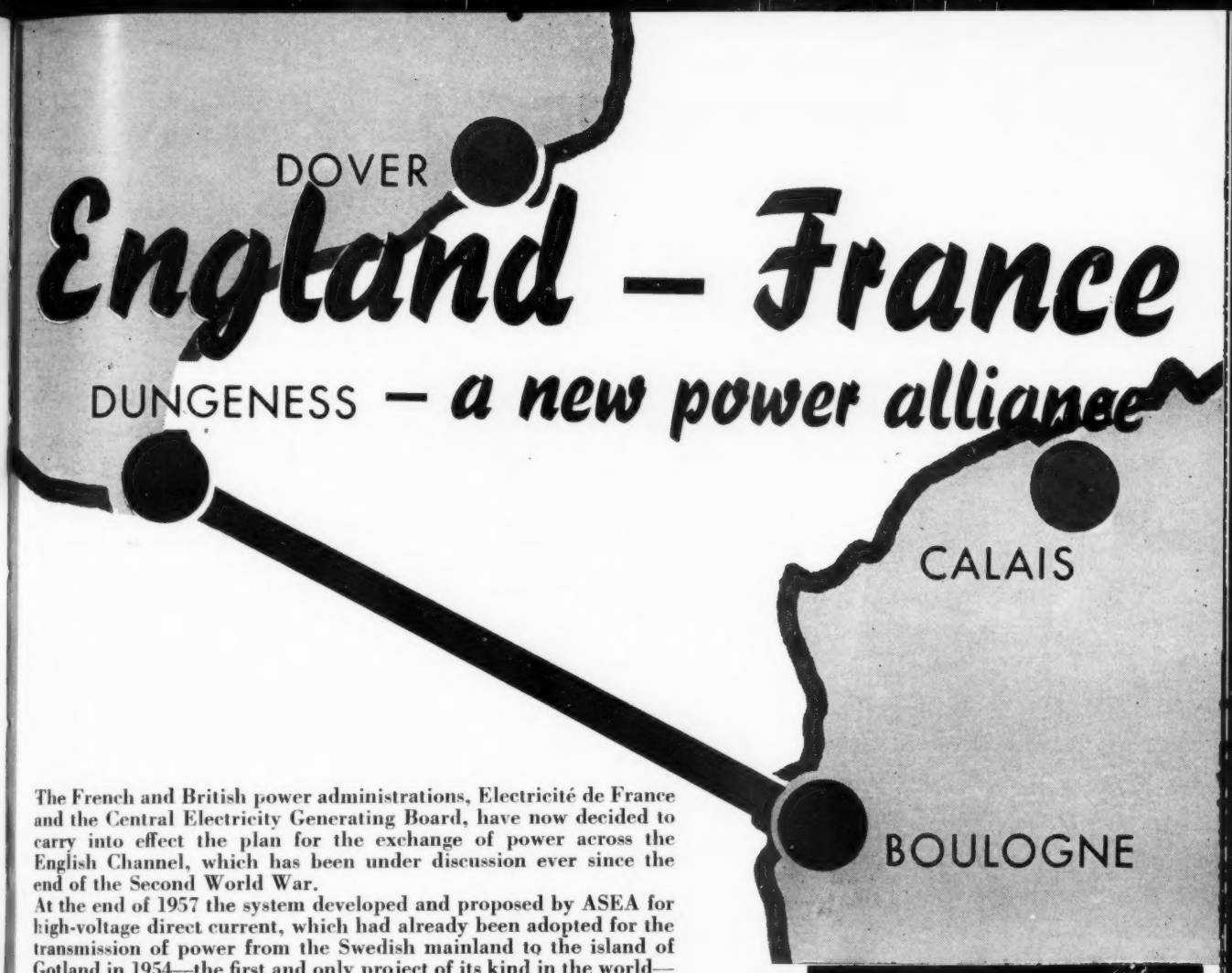
Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)

Butterfly valve with provisional downstream bulkhead

SEYHAN WATER PROJECT
• TURKEY •
THREE BUTTERFLY VALVES

- Weight of valve leaf: 110,000 lbs.
- Diameter of valve leaf: 17 ft.
- Maximum Head: 150 ft.
- Delivery: 2,600 cu. ft./sec.

FRANCO TOSI S.P.A.
LEGNANO
(IT ALY)



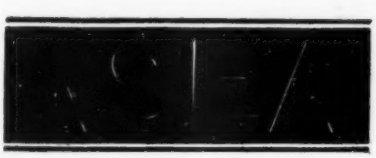
The French and British power administrations, Electricité de France and the Central Electricity Generating Board, have now decided to carry into effect the plan for the exchange of power across the English Channel, which has been under discussion ever since the end of the Second World War.

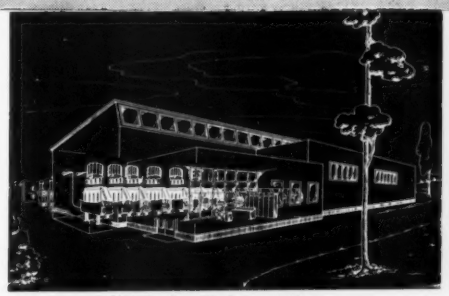
At the end of 1957 the system developed and proposed by ASEA for high-voltage direct current, which had already been adopted for the transmission of power from the Swedish mainland to the island of Gotland in 1954—the first and only project of its kind in the world—was officially accepted. The definite contract has recently been awarded to ASEA for the principal electrical equipment for the transmission in either direction of 160,000 kW, equivalent to 800 A d. c. at 200 kV. It is anticipated that the installation will be ready for commissioning by the end of 1960.

The idea behind this project is to utilise surplus power from the one country in the other country during periods of peak load. It so happens that the load peaks occur at different times of the day and during different days of the week. Despite the close proximity of the two countries, there are also certain seasonal variations in the load peaks. In addition, this project will enable both countries to postpone or even refrain from building new power stations, which would entail a considerably greater capital expenditure than the planned d. c. link.

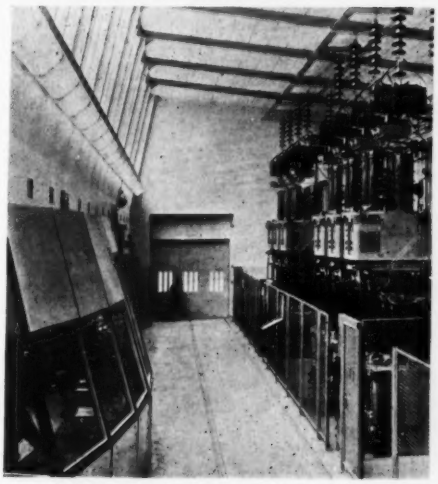
The transmission distance will be about 60 km. The converter stations are to be set up in the vicinity of Dungeness in England and Boulogne in France. It is intended to connect the d. c. link to the English 275 kV, 50 c/s grid, and to the French 225 kV, 50 c/s grid.

The ASEA d. c. system, which was selected in the face of severe competition from other alternative solutions, offers considerable advantages. The number of transmission cables can be limited, the installation costs are lower and the likelihood of mechanical faults less. Furthermore, the d. c. link will enable the network frequency of the one country to be regulated independently of that in the other country.

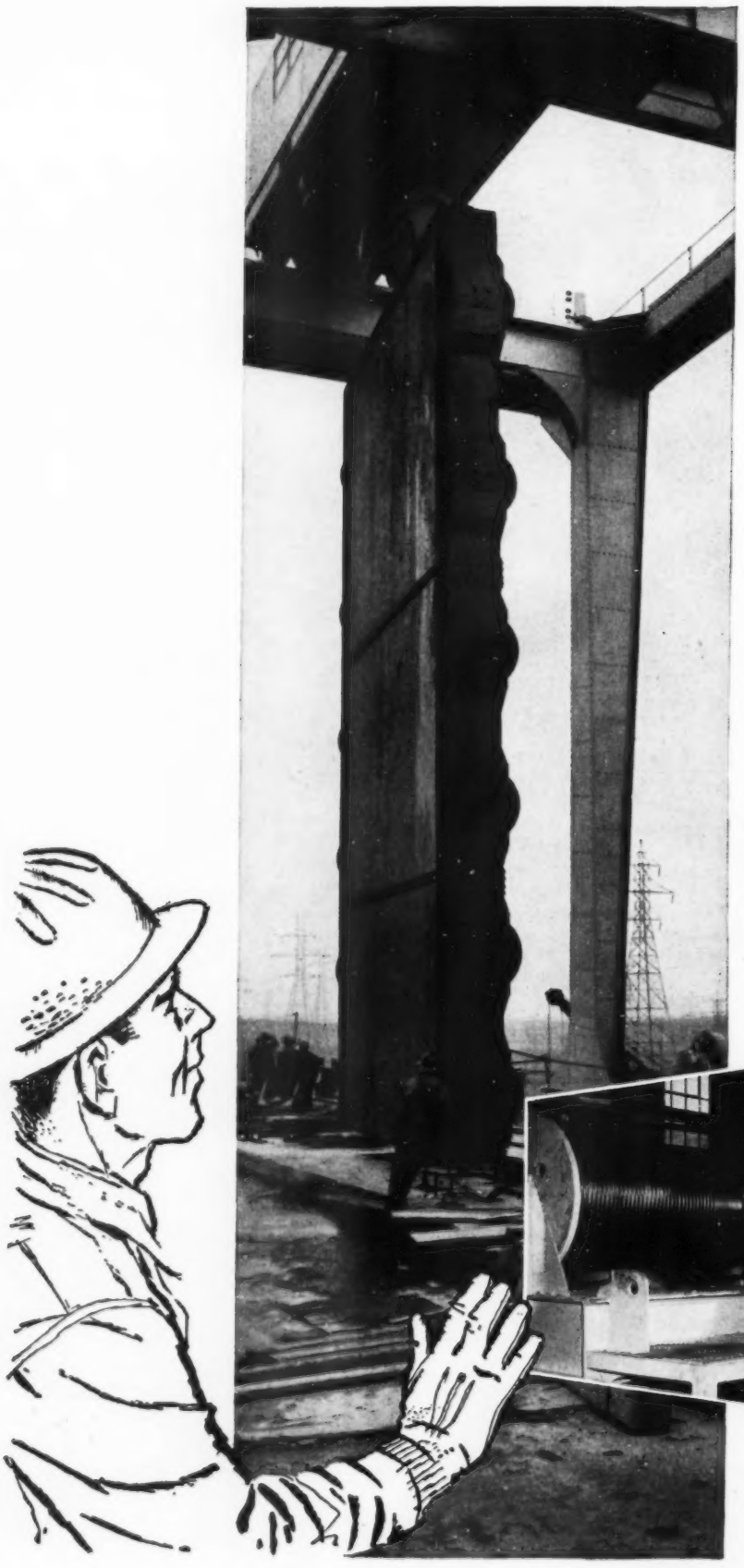
Västerås  Sweden



Sketch of a converter station.



Valve hall in one of the converter stations for the d.c. transmission system to Gotland, in operation since 1954.



Intake Gates

Illustrated is a completely assembled Intake Gate being lowered into position. This is one of twelve built by Canadian Vickers for the Pumped Storage Scheme part of the Sir Adam Beck No. 2 Development of the Hydro Electric Power Commission of Ontario, at Queenstown.

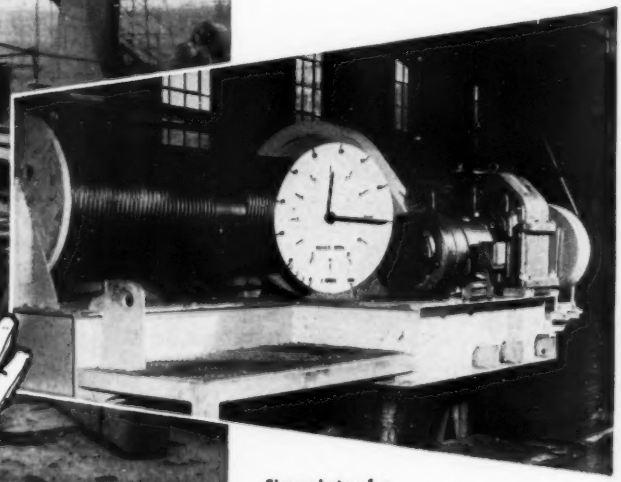
Shop welded in sections and riveted together in the field, these Gates are designed for a clear opening of 16′-8¾″ wide and 34′-9″ high and subjected to a maximum head on thesill of 77′-6″.

Canadian Vickers designs and builds all types of Water-Way and Water-Power equipment. If it is Vickers-built . . . it's right.

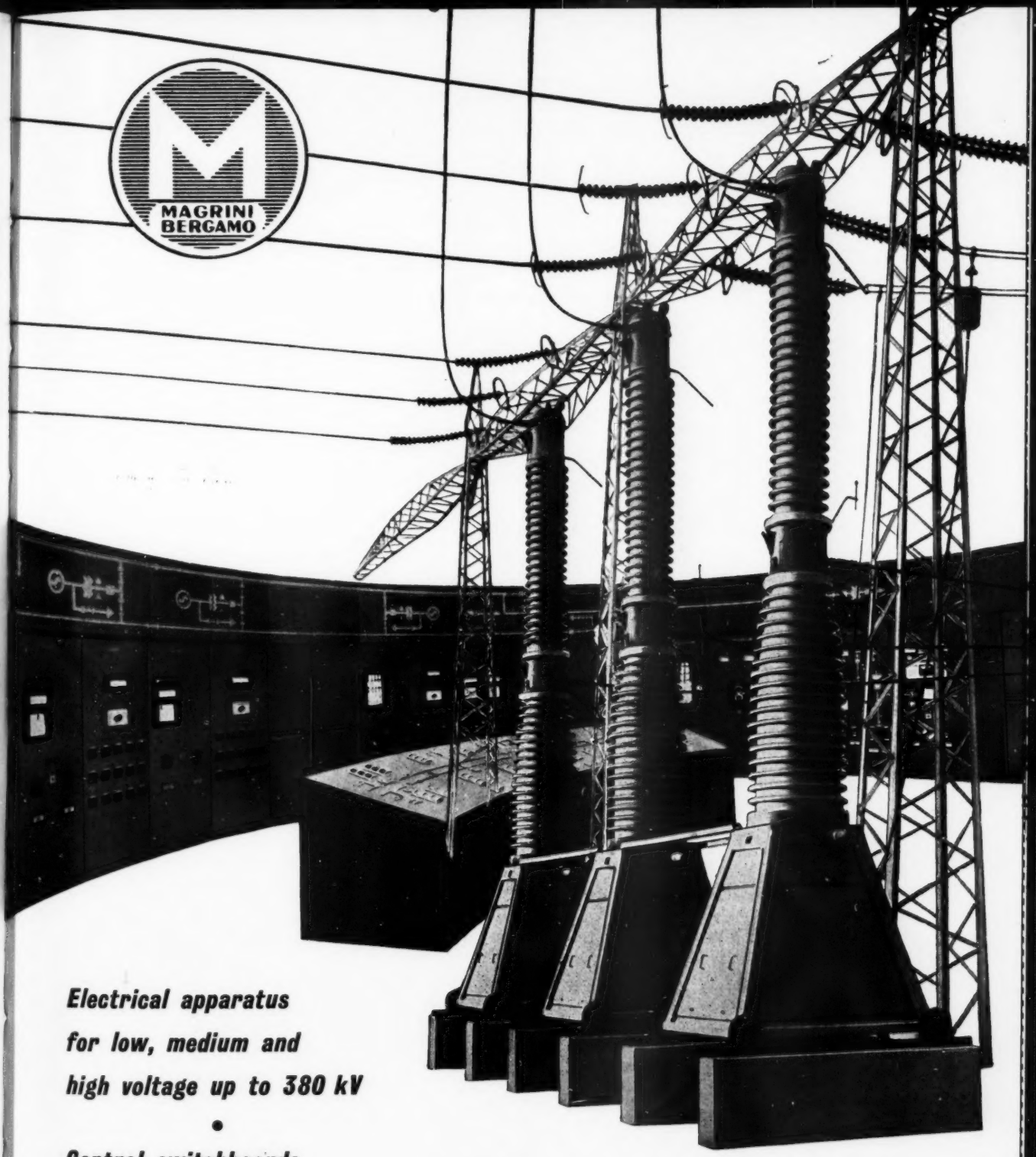
CANADIAN VICKERS LIMITED

MONTREAL TORONTO

CANADIAN MEMBER OF THE VICKERS GROUP



Shop photo of a Vickers-built Hoist.



Electrical apparatus for low, medium and high voltage up to 380 kV

•

Control switchboards and control desks

•

Indoor and outdoor metal clad switchgear

•

Lightning arresters

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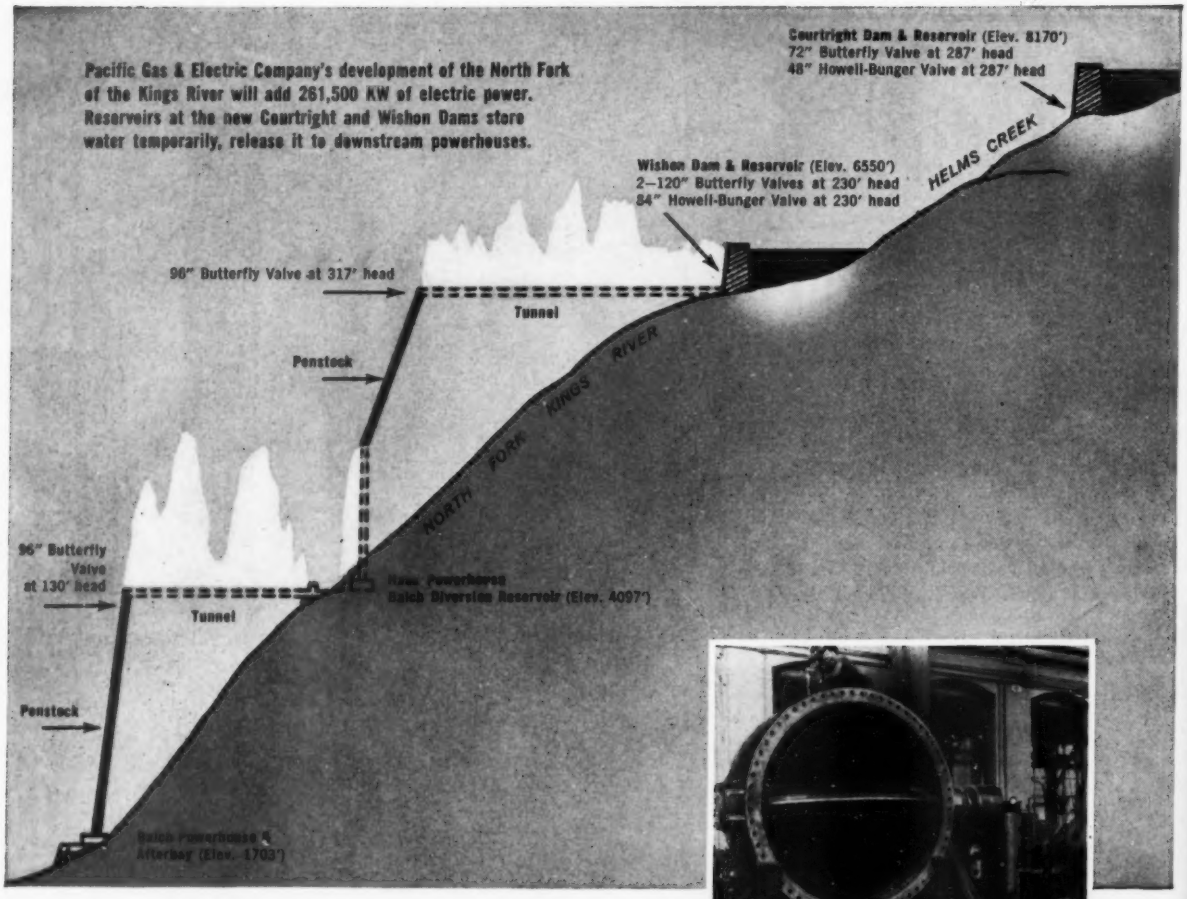
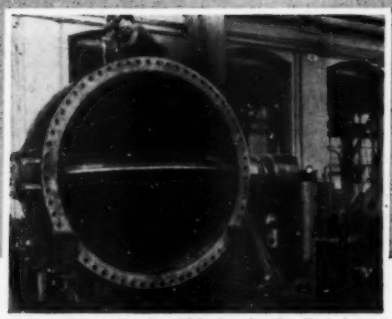
SALES AGENTS IN ITALY AND ABROAD


Pacific Gas & Electric Company's development of the North Fork of the Kings River will add 261,500 KW of electric power. Reservoirs at the new Courtright and Wishon Dams store water temporarily, release it to downstream powerhouses.
Courtright Dam & Reservoir (Elev. 8170')
72" Butterfly Valve at 287' head
48" Howell-Bunger Valve at 287' head
HELMS CREEK
Wishon Dam & Reservoir (Elev. 6550')
2—120" Butterfly Valves at 230' head
84" Howell-Bunger Valve at 230' head
96" Butterfly Valve at 317' head
Tunnel
Penstock
NORTH FORK KINGS RIVER
96" Butterfly Valve at 130' head
Tunnel
Haas Powerhouse
Balch Diversion Reservoir (Elev. 4097')
Penstock
Balch Powerhouse
Alterbay (Elev. 1703')



During shop tests, the 96-inch valve for Haas tunnel demonstrates the streamlined construction of SMS welded steel plate discs. This reduces head loss and turbulence to a minimum.

Kings River Project installs SMS valves

Five SMS Butterfly Valves and two SMS Howell-Bunger Valves are being installed by Pacific Gas & Electric Company on its Kings River hydropower project in the Sierra and Sequoia National Forests. They will control the flow of water from upstream reservoirs to the powerhouses in this $80 million system.

Seals on SMS Butterfly Valves cut leakage to a minimum. Disc and body seals are adjustable from either inside or outside, as specified. Specially-developed SMS trunnion seals are essentially drop-tight. Welded discs and housings assure freedom from the defects of cast materials, and permit more economical construction.

SMS Butterfly Valves have been designed and built in diameters up to 18 feet, and for service with operating heads up to 750 feet. To obtain information on SMS hydraulic turbines, valves and other accessories, write to S. Morgan Smith Company, York, Penna.

One of the 120-inch Wishon Reservoir valves on the SMS assembly floor shows adjustable seals on the discs and recess for the renewable seal ring within the body.

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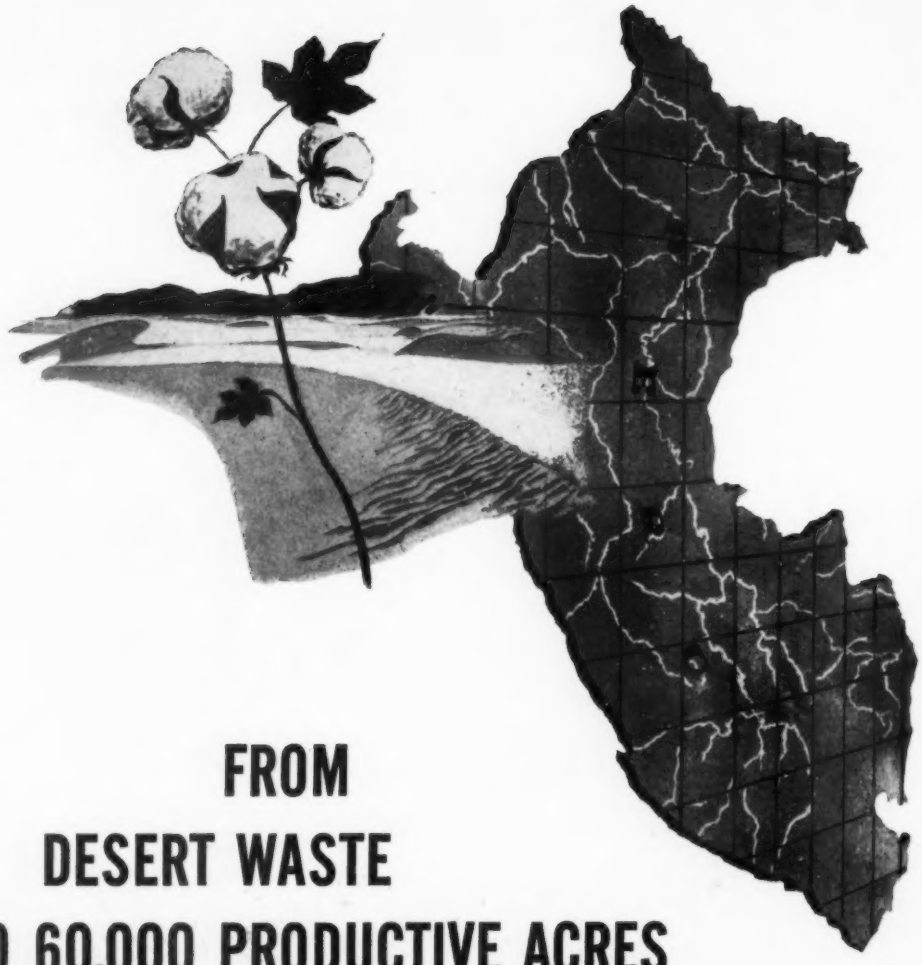

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Nearing completion in northern Peru's Rio Quiroz basin is the San Lorenzo Dam, a massive earth-fill structure that will impound a quarter of a billion cubic meters of water behind its quarter-mile span . . . water to irrigate 60,000 acres of new land through a modern system of canals and laterals.

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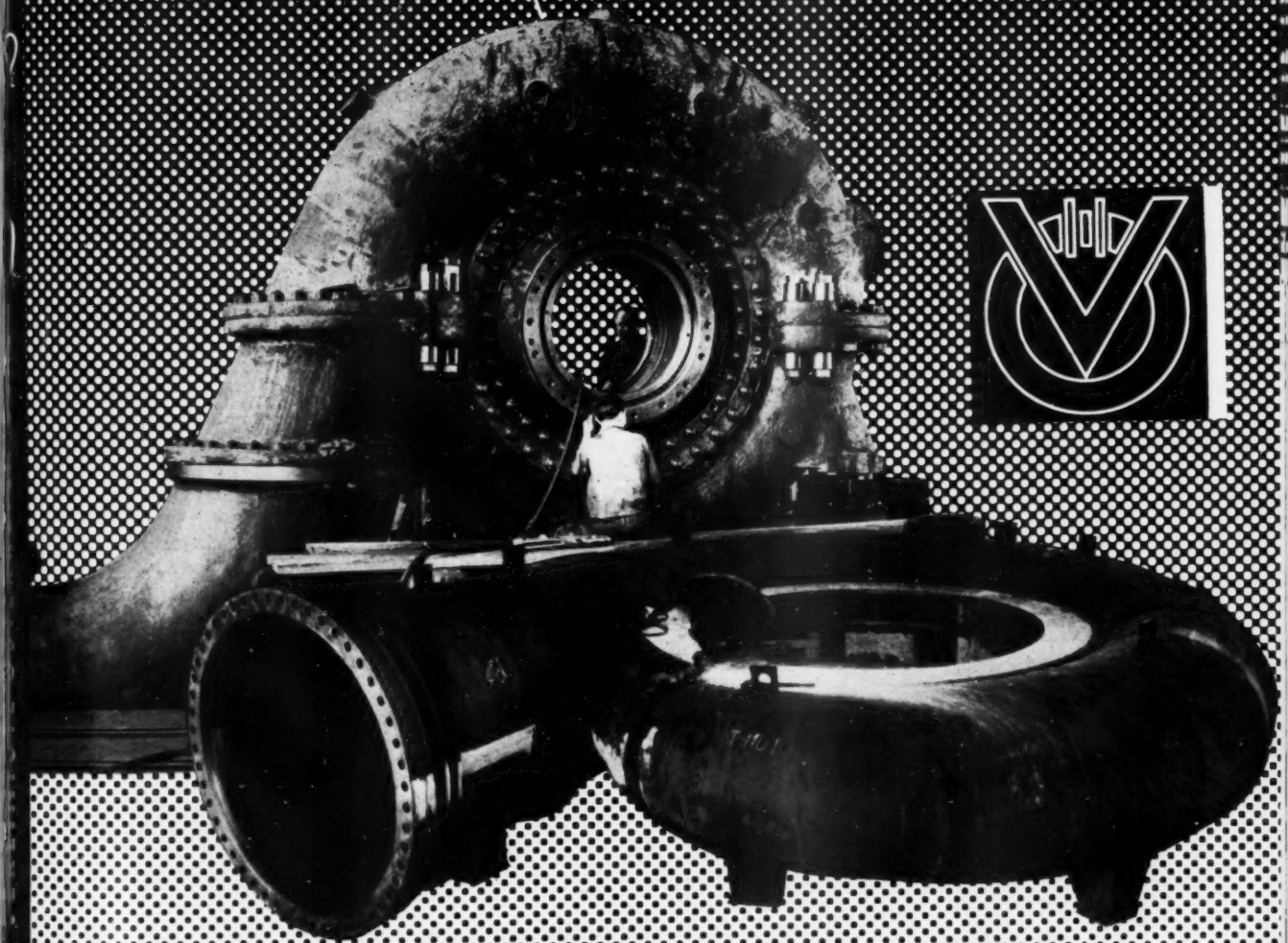

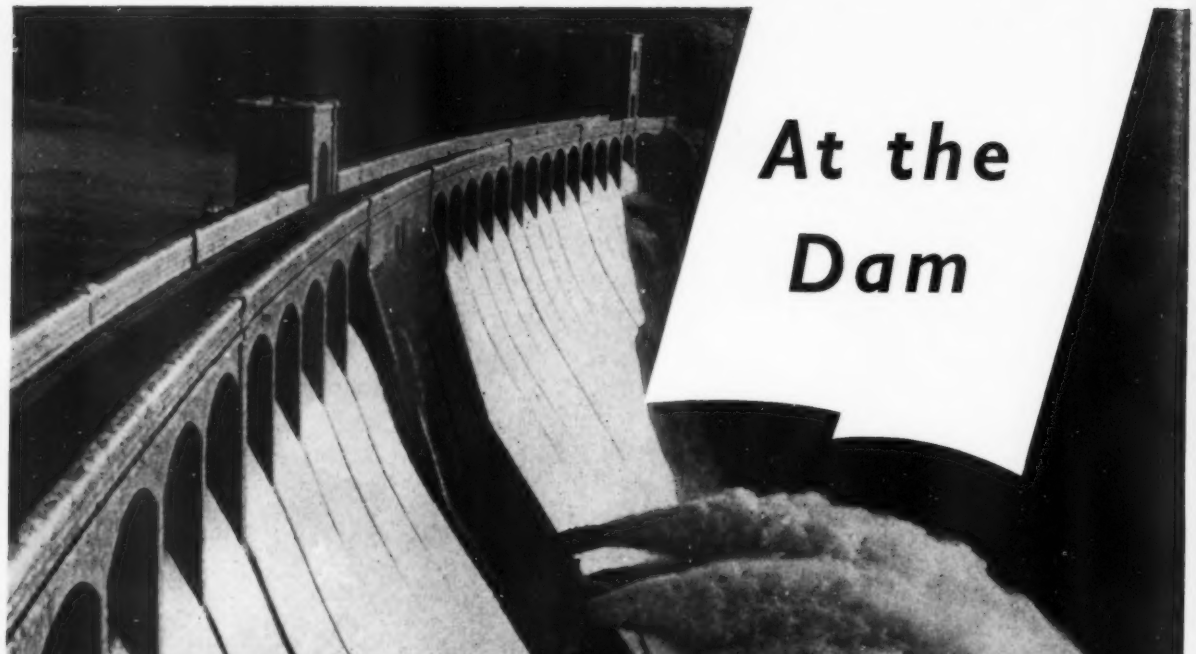

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The Glenfield Jet Disperser offers a complete answer to problems involving the dissipation of the energies in freely discharging high velocity water jets.

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The site illustration shows a battery of six Glenfield Jet Dispersers on a siphon spillway, each designed to pass 620 cusecs and dissipate a total of some 25,000 h.p. in the process.

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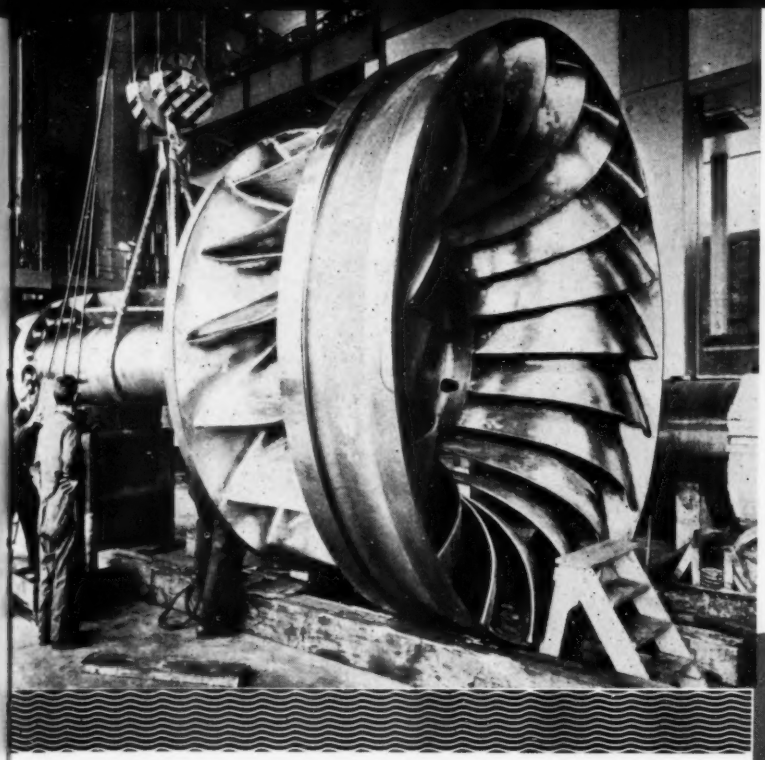
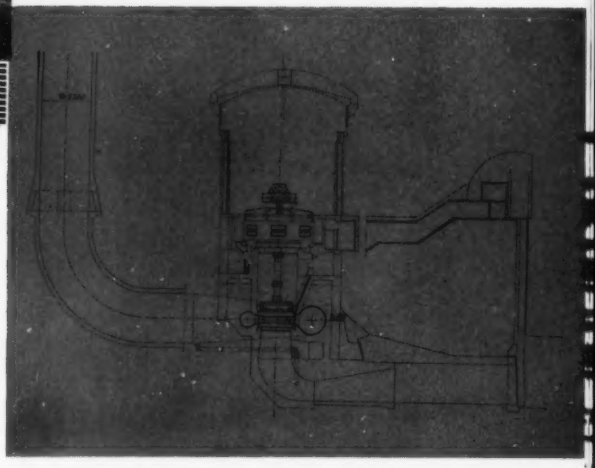


Turbines to talk about

The last stage in the erection of the third Francis turbine for the Swedish power station Ramsele, belonging to the Krångede AB, Stockholm, is now being completed. The other two turbines were put into service this summer. With the installation of this third unit, Ramsele Power Plant will be completed and will then have a guaranteed output of 206,490 h.p. at a net head of 243 ft. and 187 r.p.m. The runners are made of stainless steel cast in one piece.



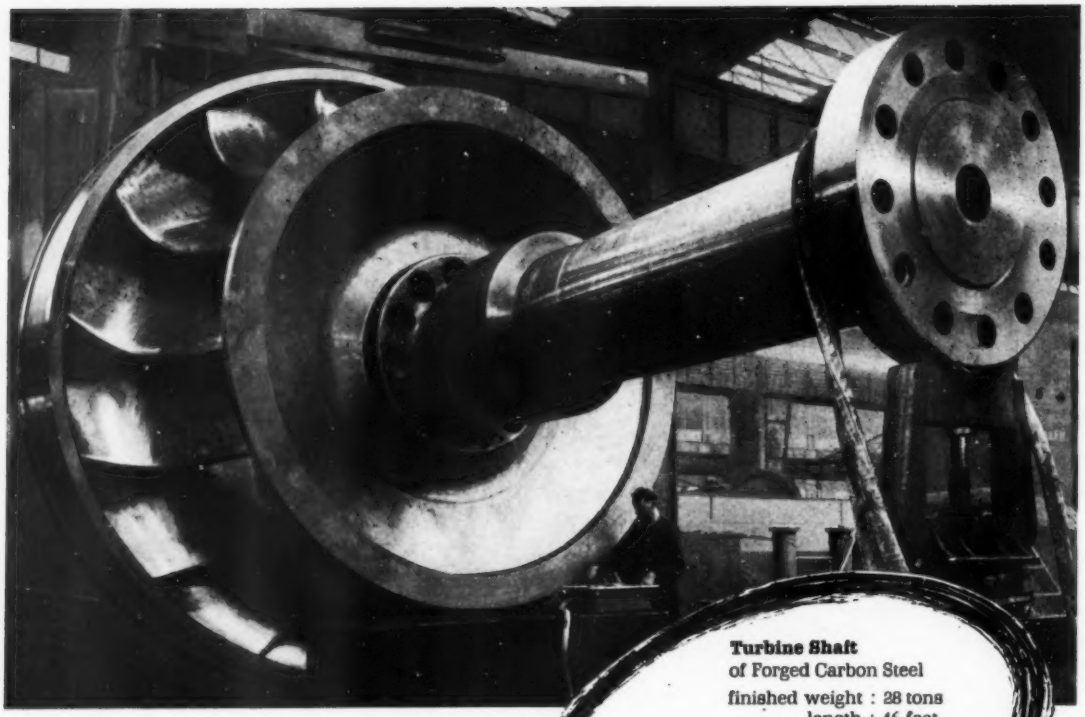
Cross section through the power station of Ramsele

Client	Plant	Number of units	Total output	Net head ft.	r.p.m.	Remarks
Saltos del Sil S.A., Madrid, Spain	San Esteban	4	362,800	338	214	Fourth unit in service 1957
Harrsele AB, Stockholm, Sweden	Harrsele	3	264,210	173	125	in service 1958
A. Johnson & Co. (Canada) Ltd., Montreal, Canada	Willson	1	82,000	263	180	in service 1957
Stora Kopparbergs Bergslags AB, Falun, Sweden	Trängslet	2	280,000	459	214	under construction
AB Mölnbacka-Trysil-Höljes Kraftverk, Forshaga, Sweden	Höljes	2	182,800	284	187·5	under construction
Swedish State Power Board, Stockholm, Sweden	Stalon	1	150,170	623	250	on order

AB KA[redacted]KANISKA WERKSTAD **KMW**

[redacted] — SWEDEN

REPRESENTA[redacted] JOHNSON & CO. (CANADA) LTD., 607 SHELL TOWER BUILDING, MONTREAL 2



Turbine Shaft
of Forged Carbon Steel
finished weight : 28 tons
length : 16 feet
flange dia. : 59 inches
shaft dia. : 35 ½ inches

Francis Runner
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integrally cast in one piece
finished weight : 65 tons
dia. : 18 feet
height : 9 feet

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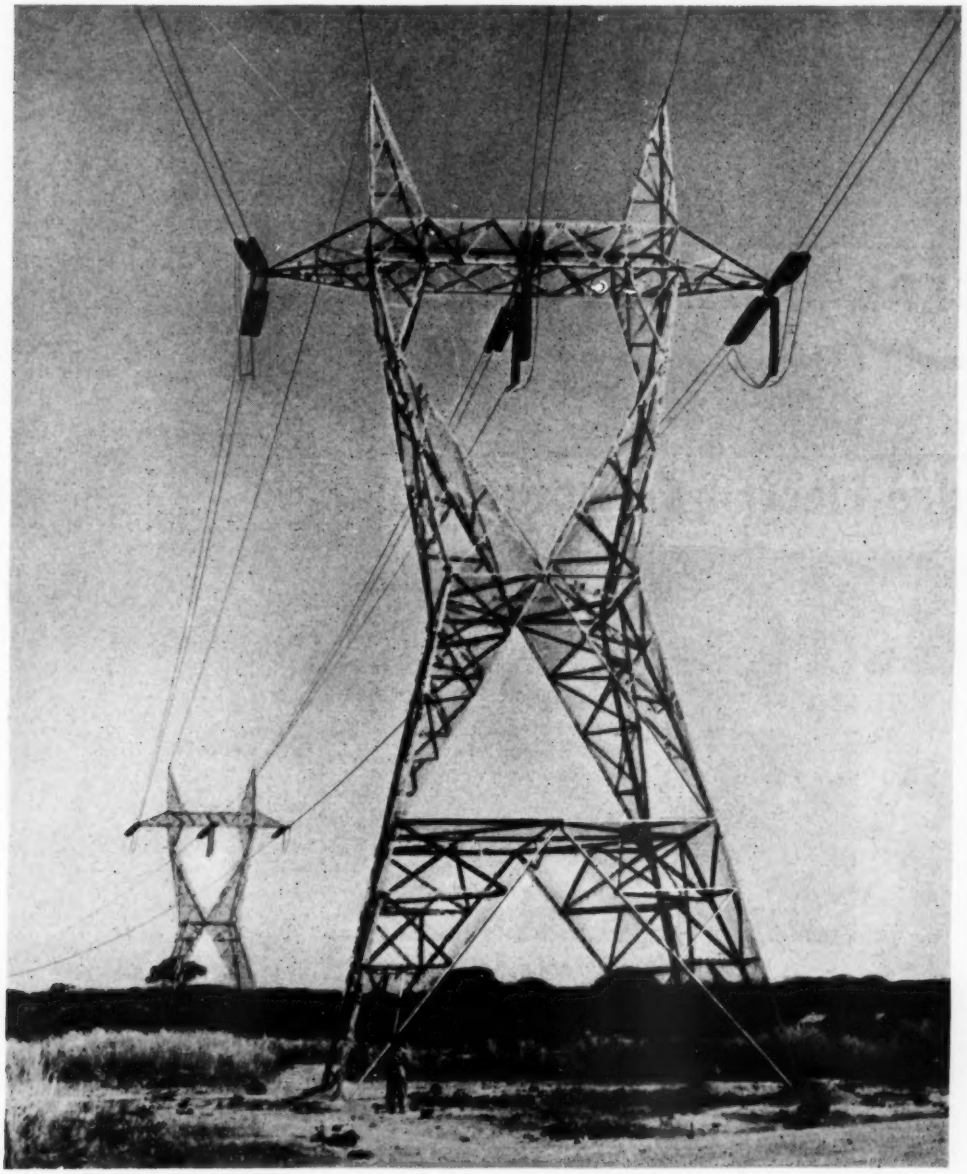

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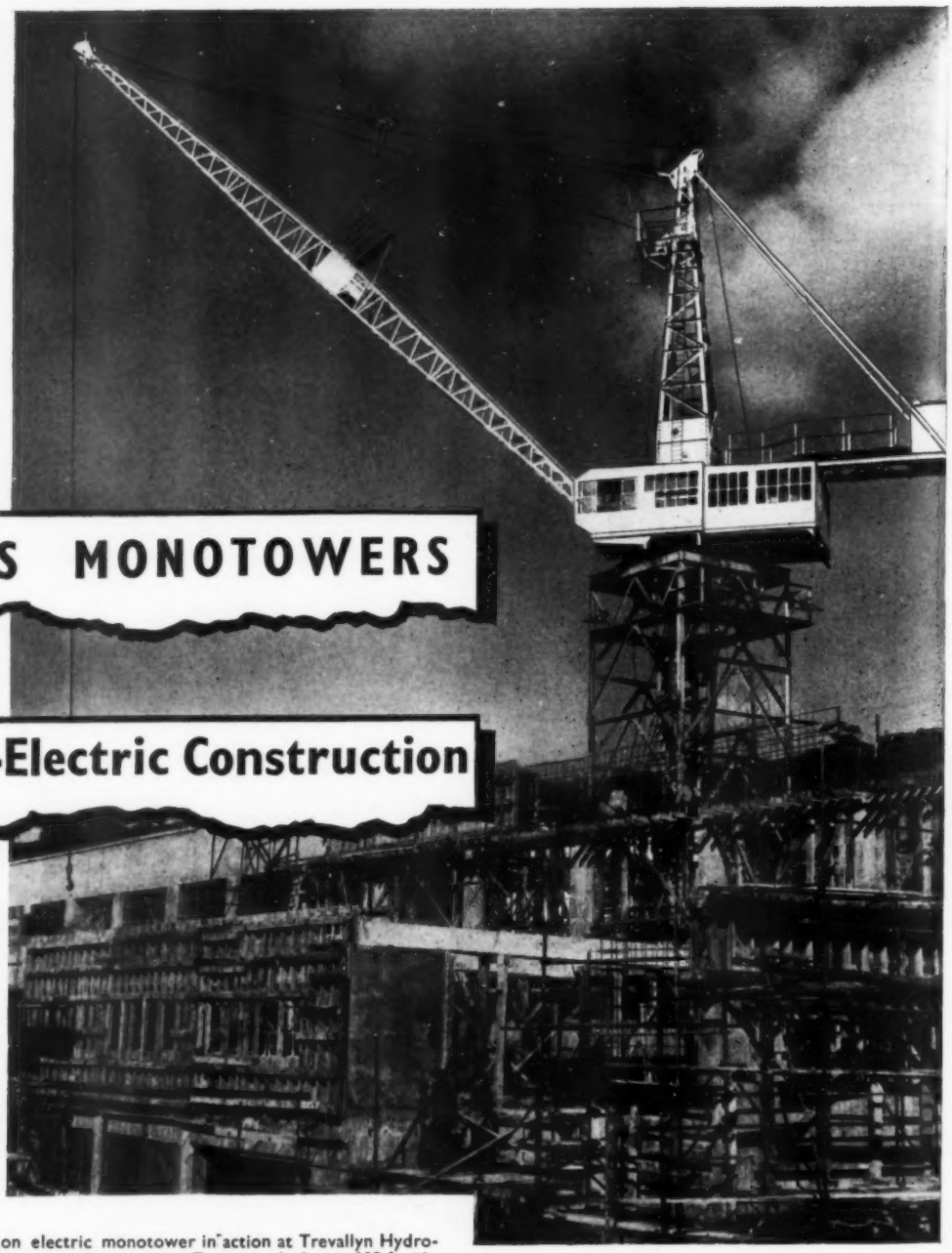

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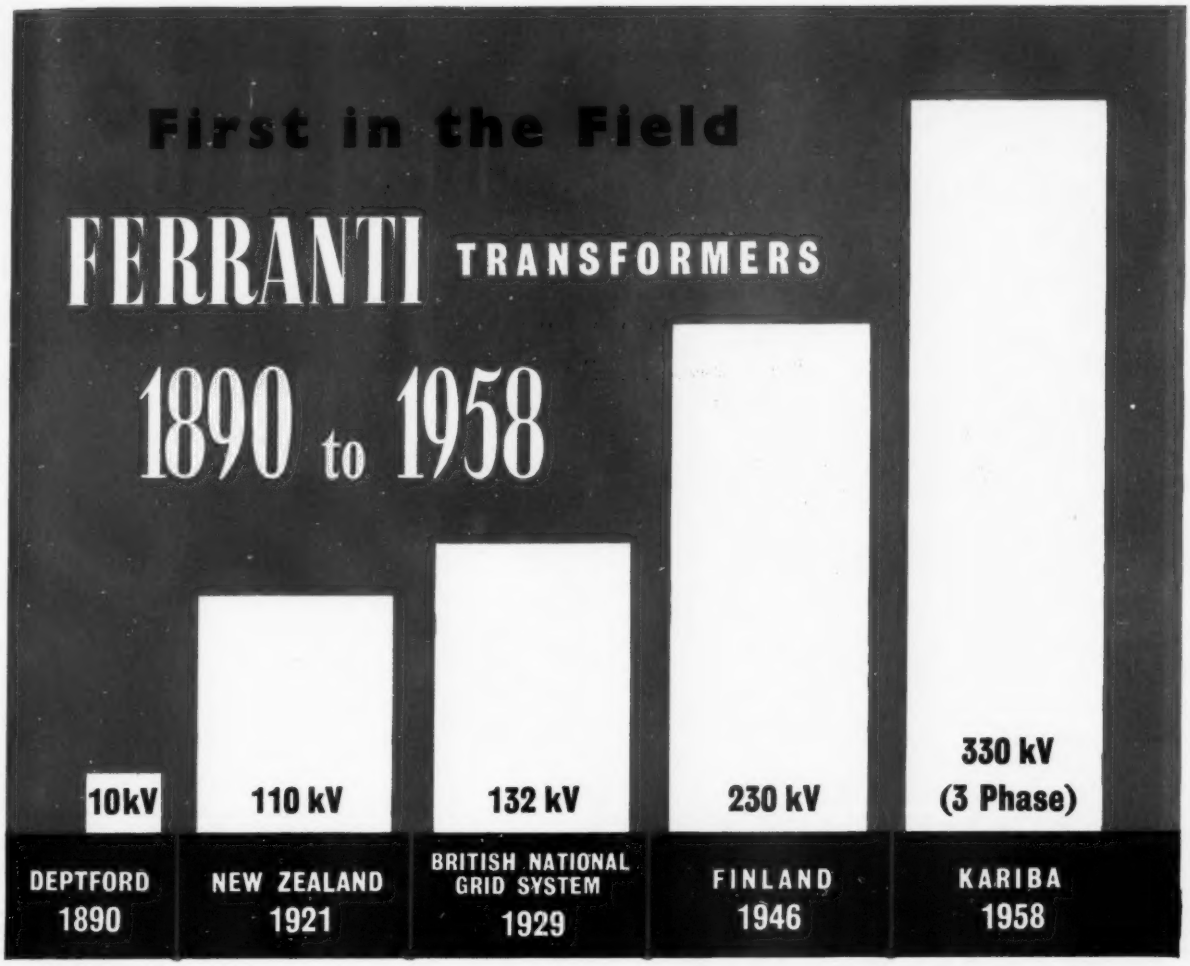

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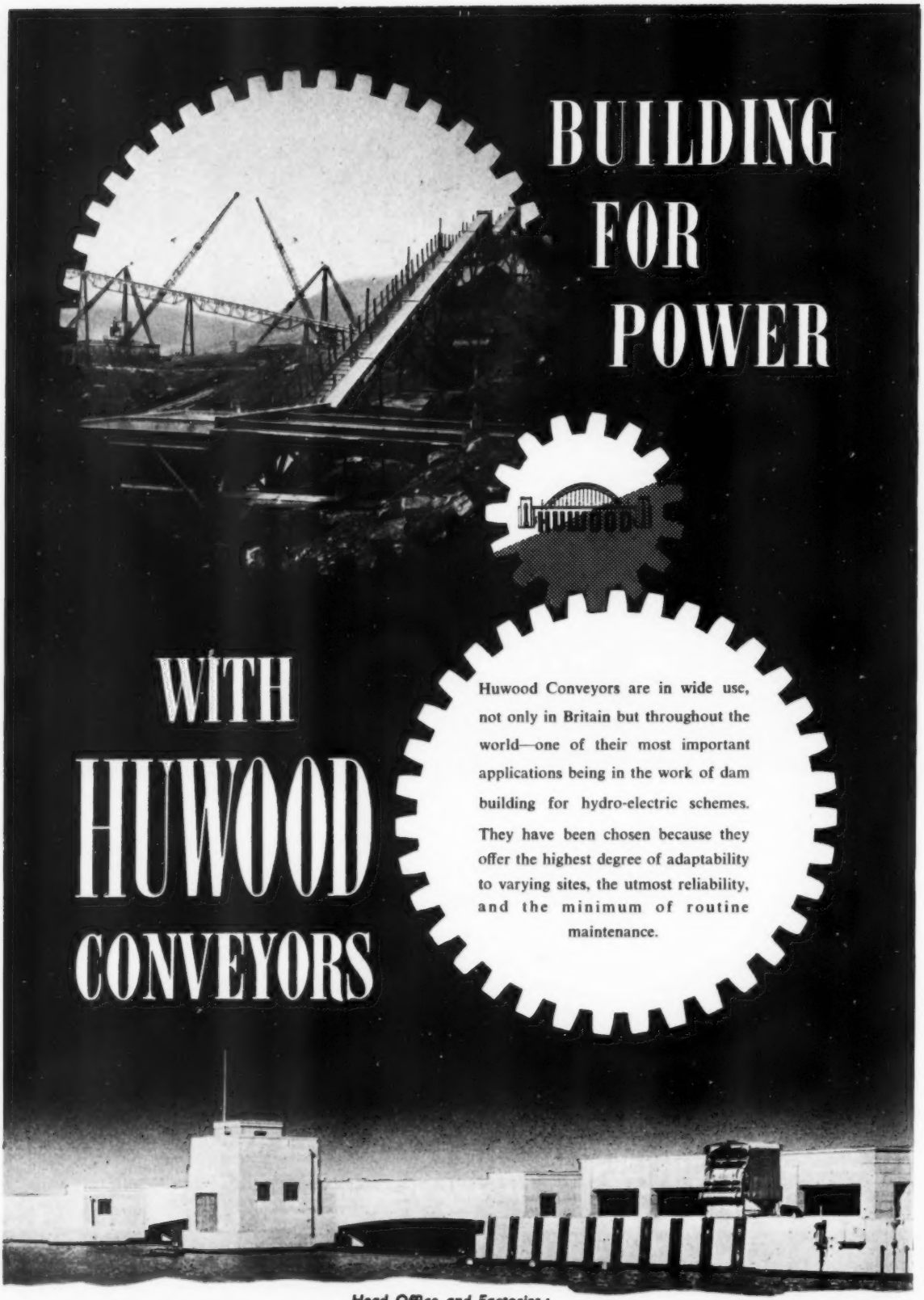
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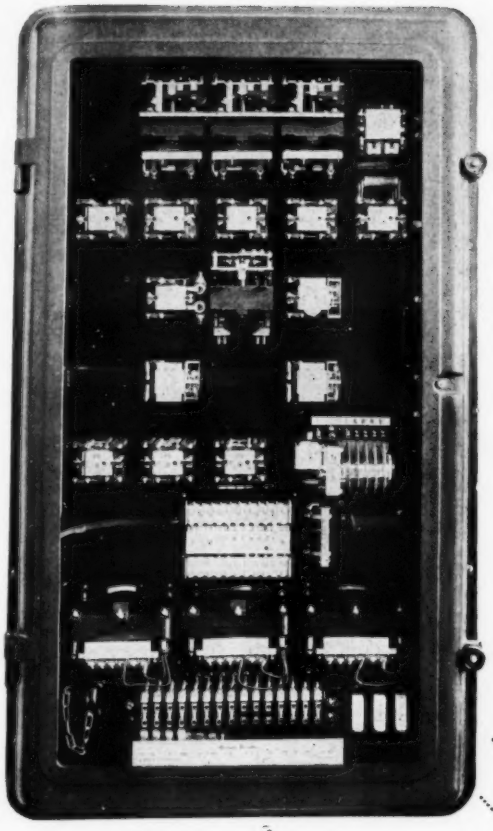

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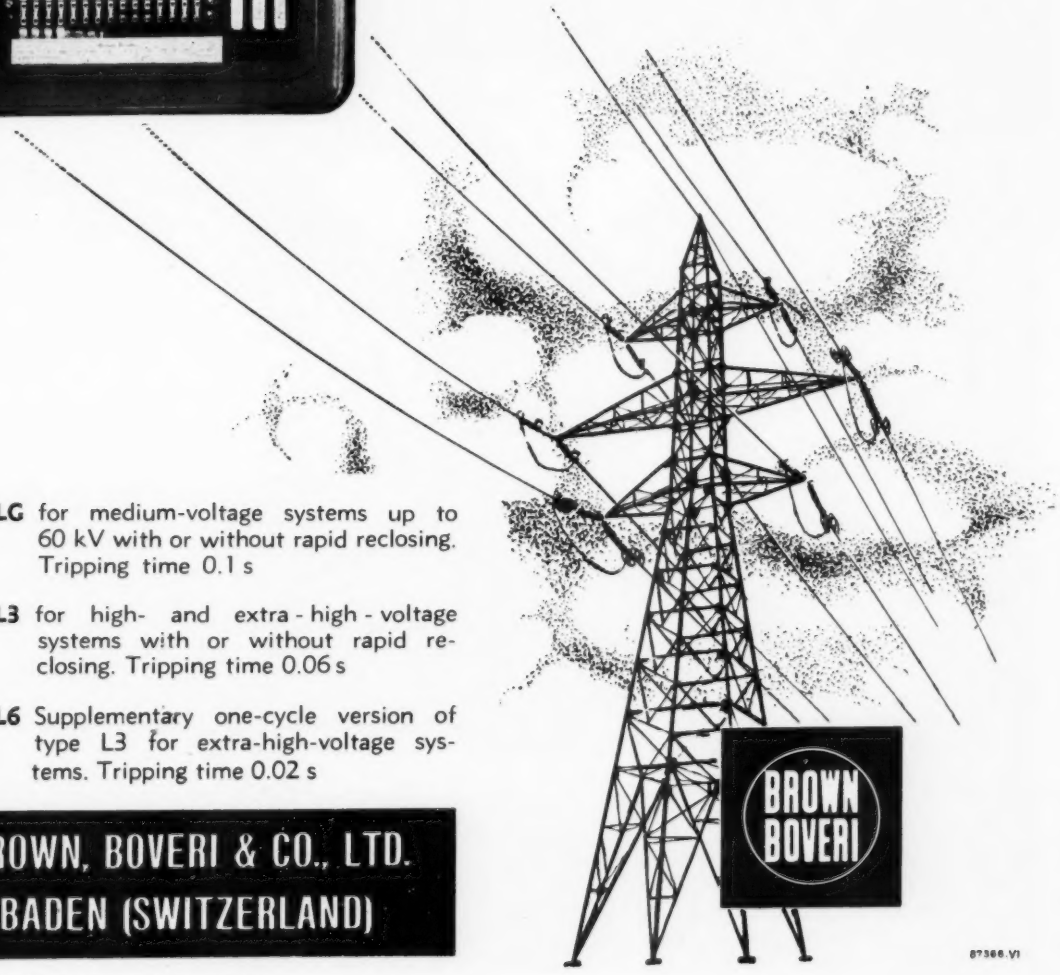

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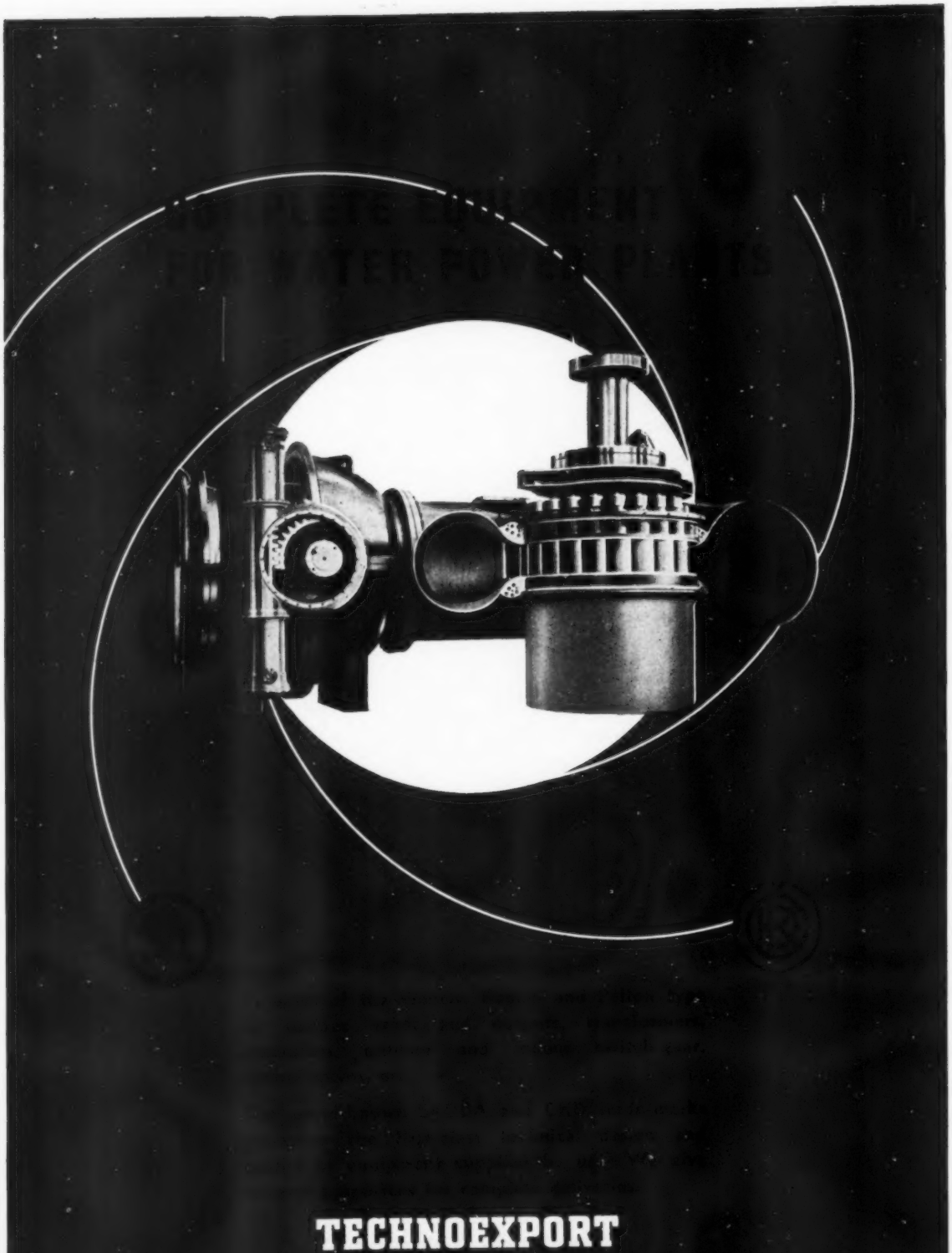
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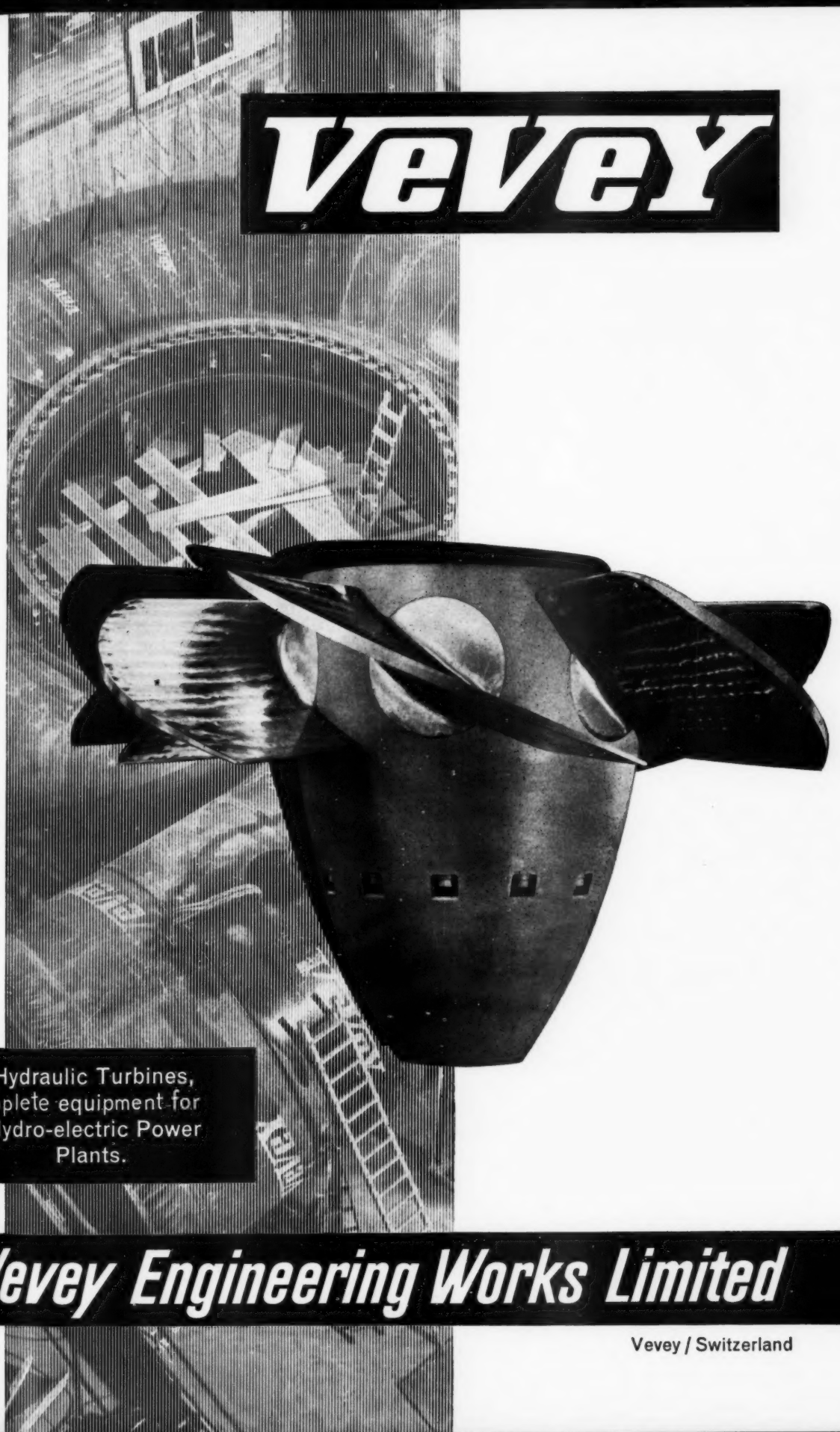

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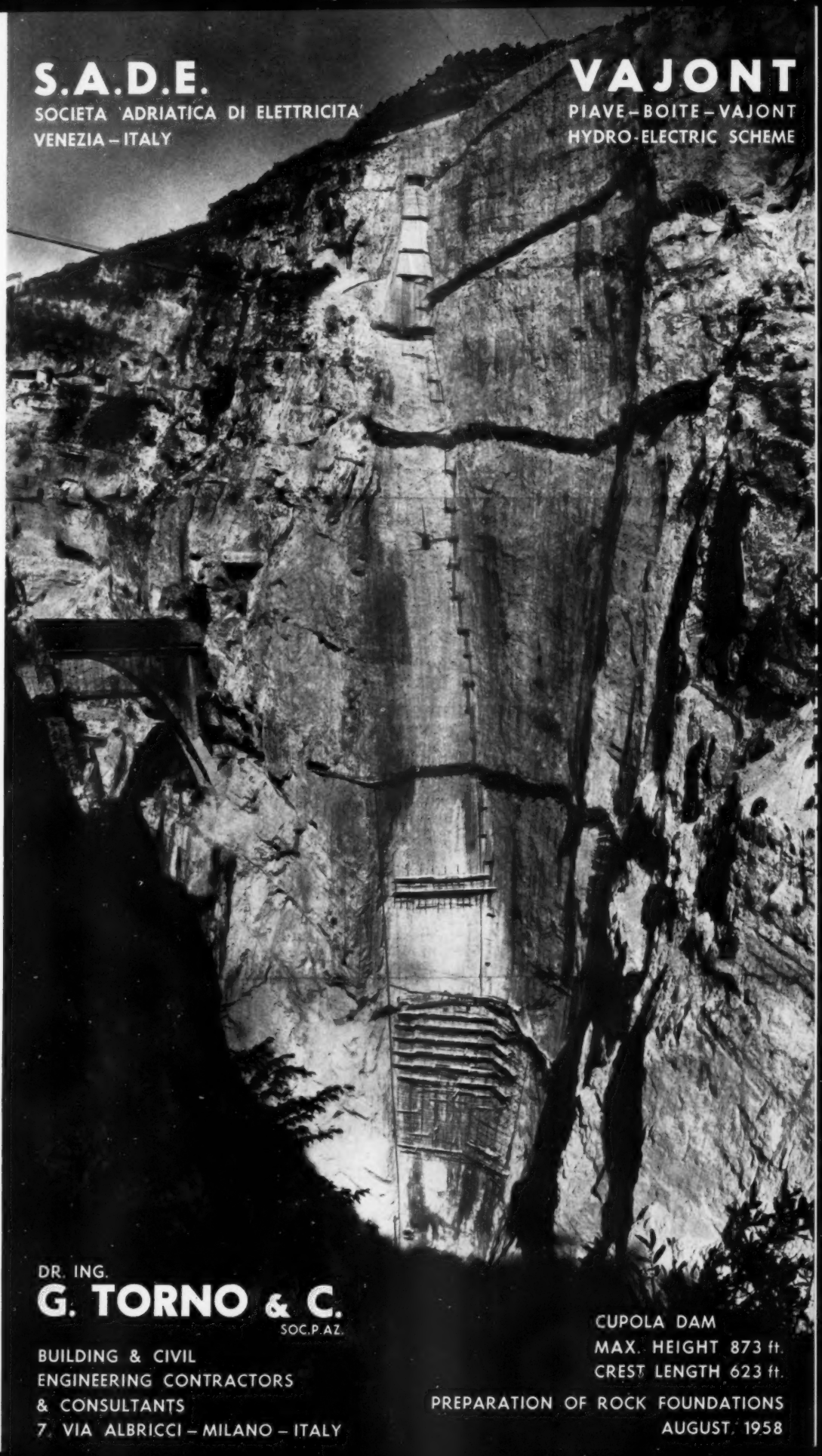
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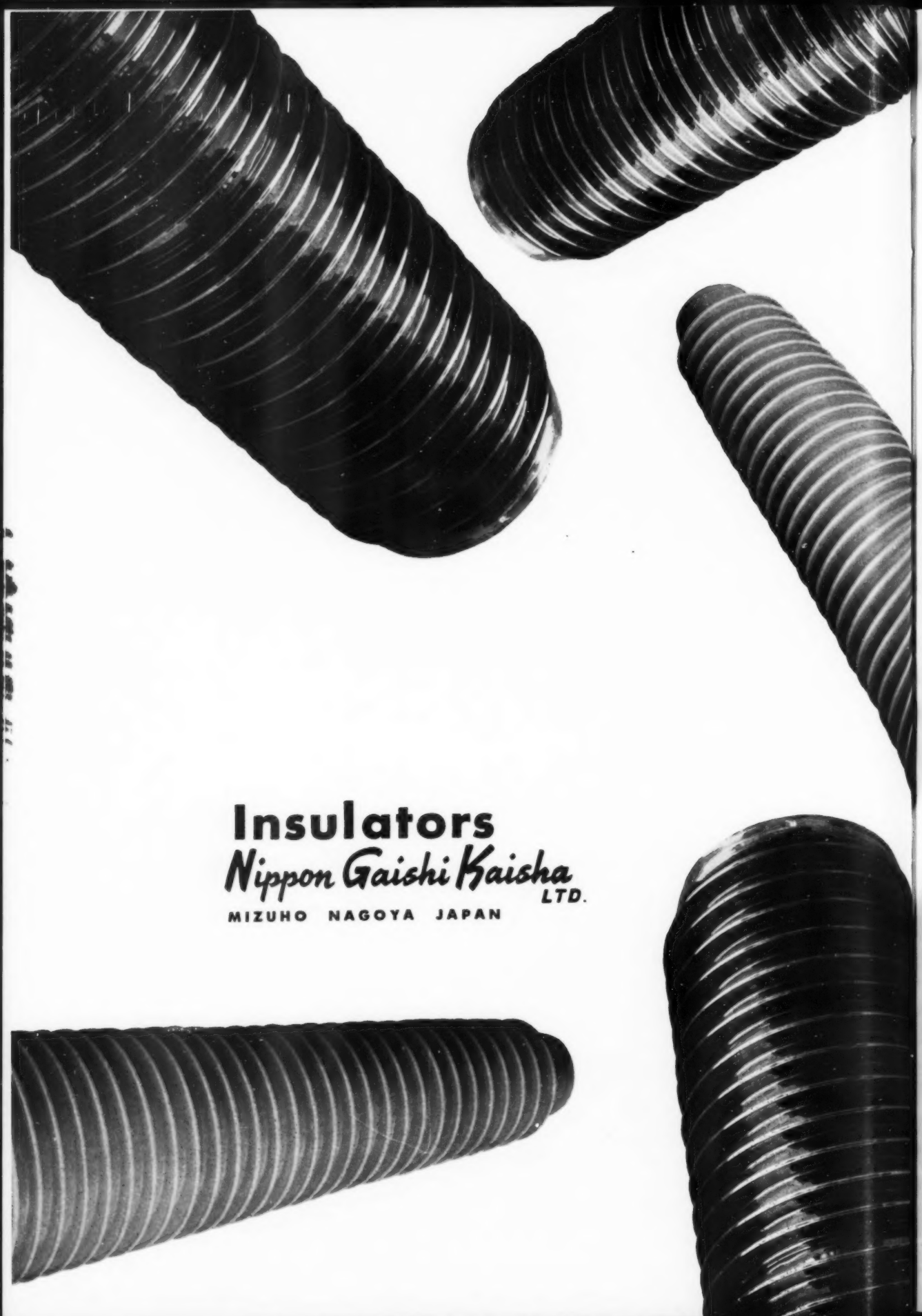
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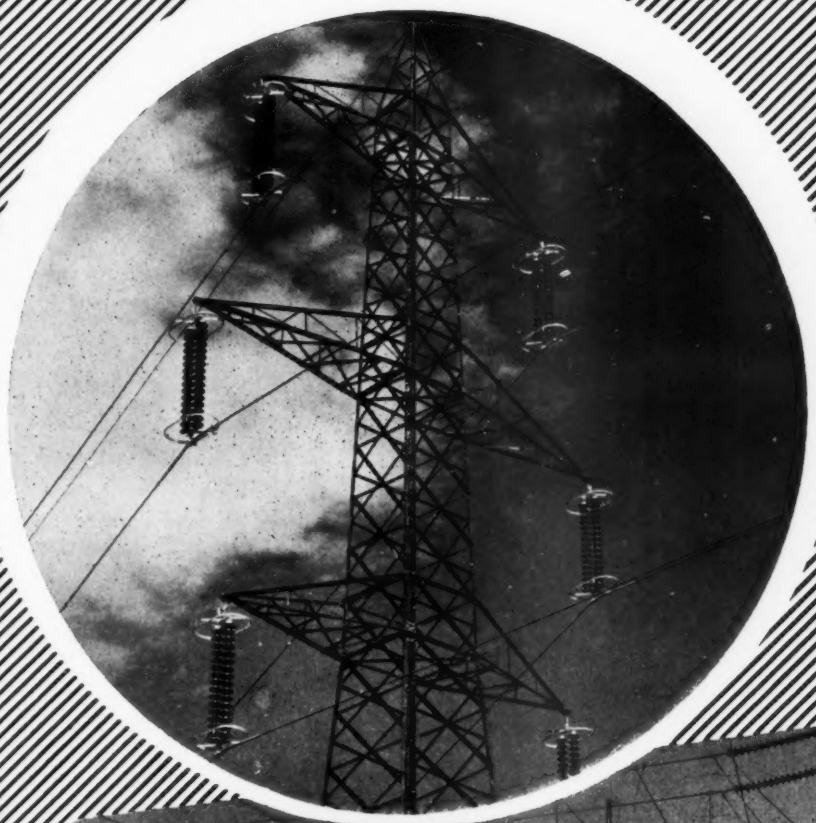

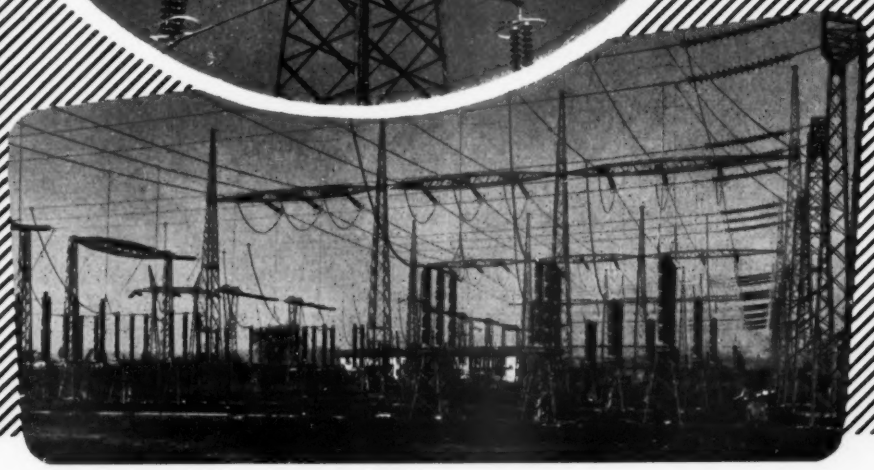

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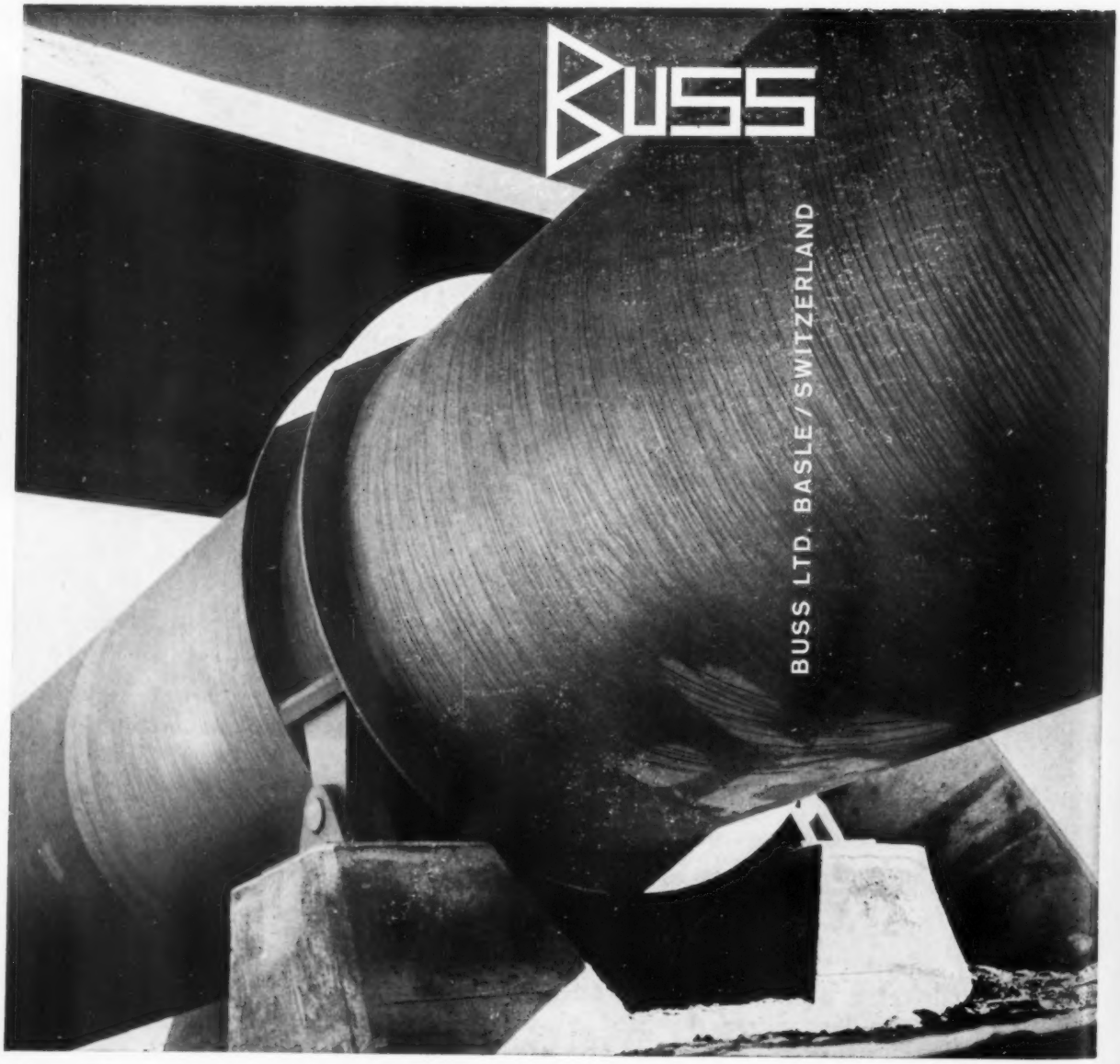

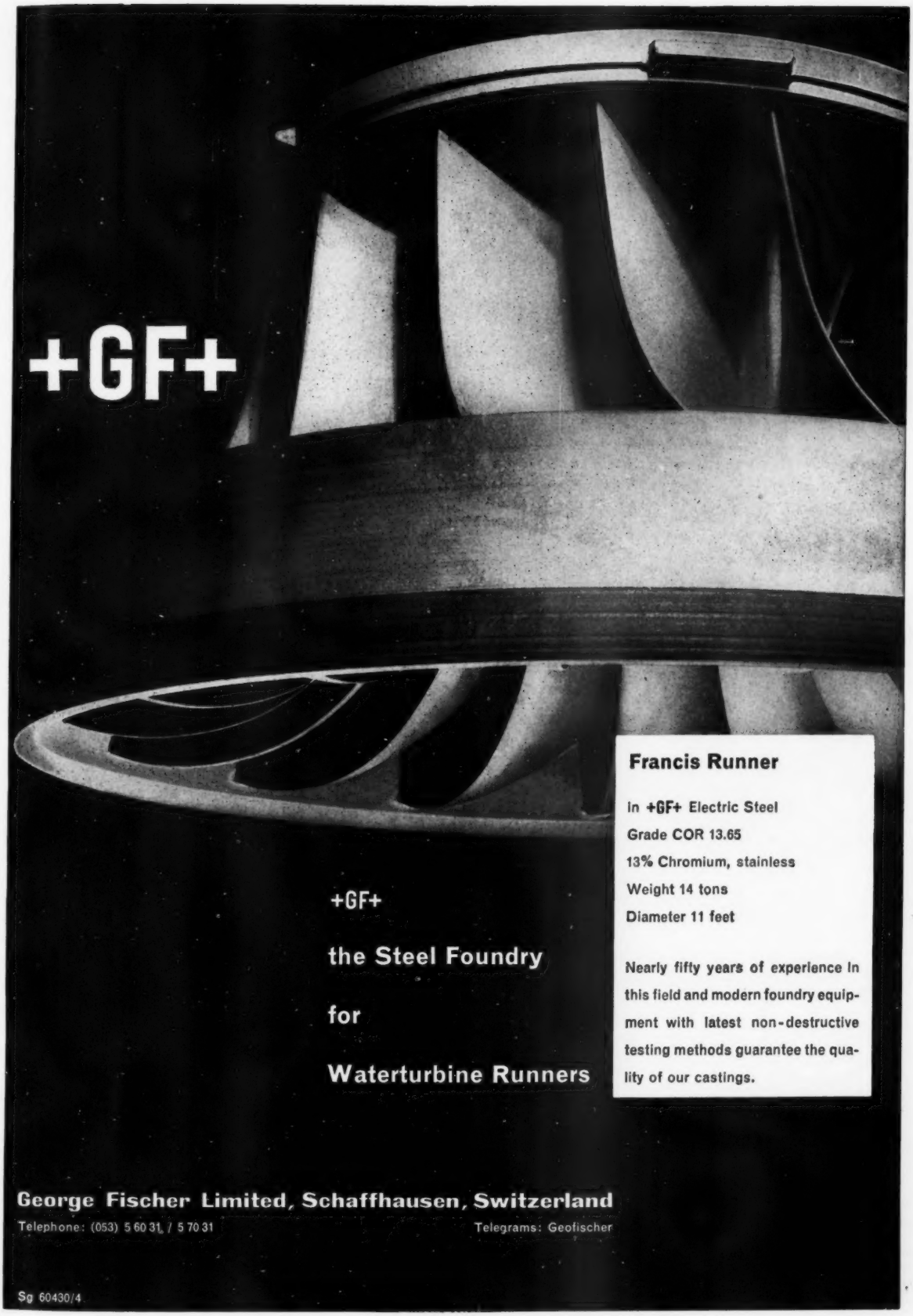
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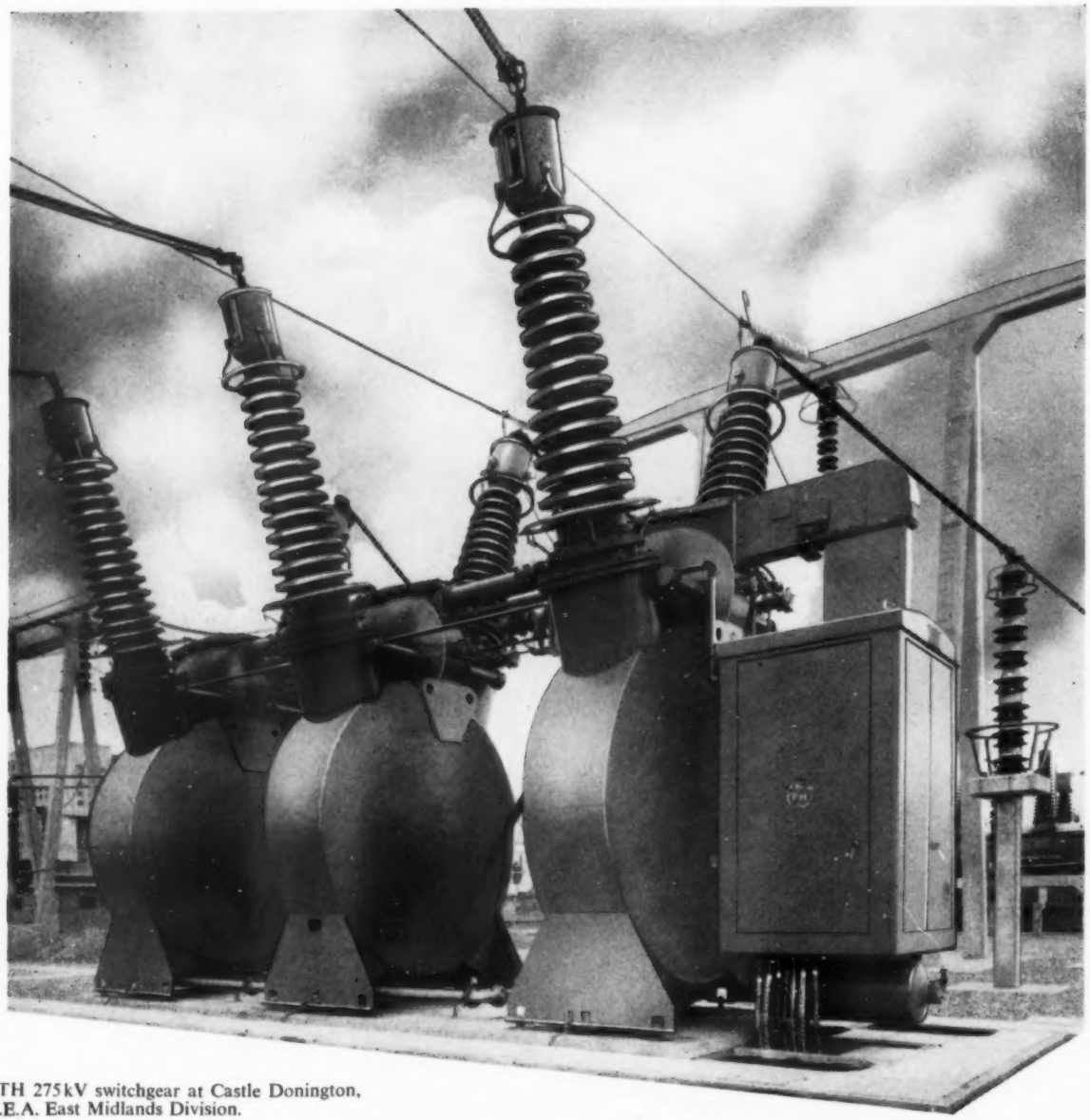

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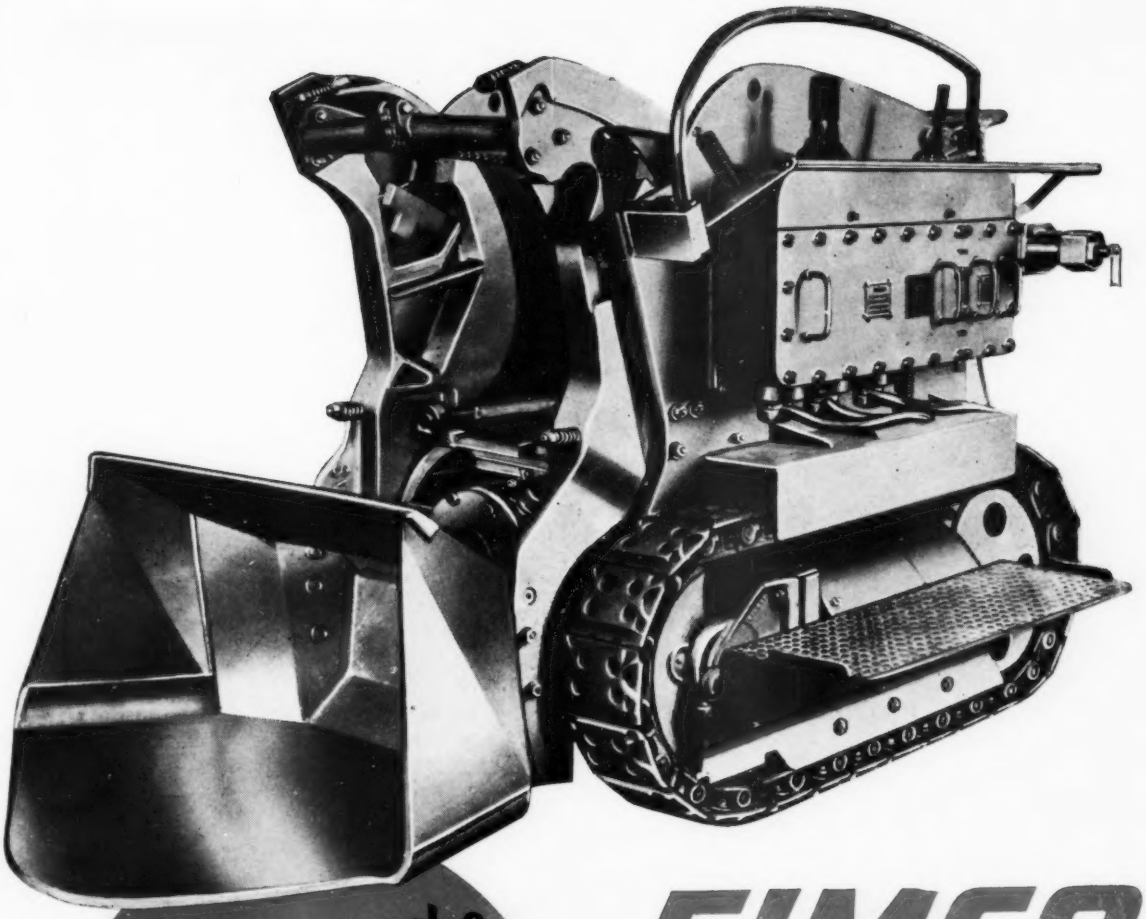

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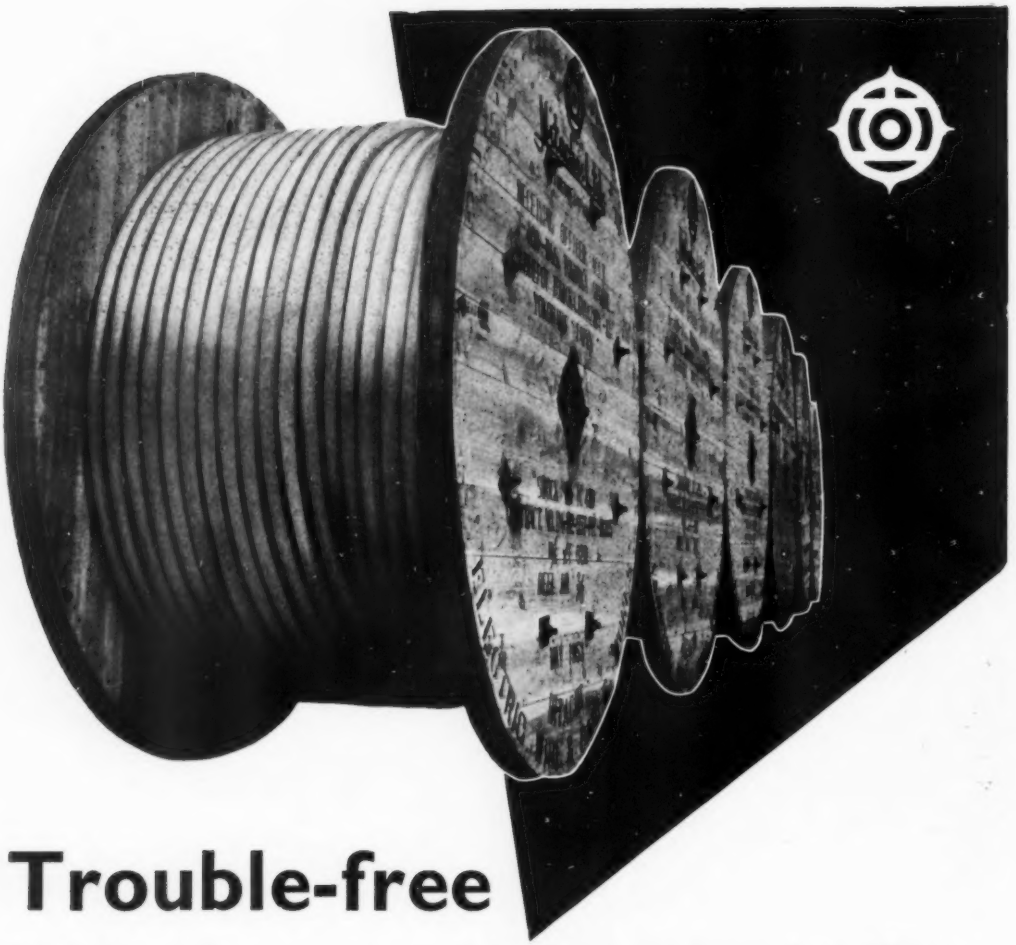

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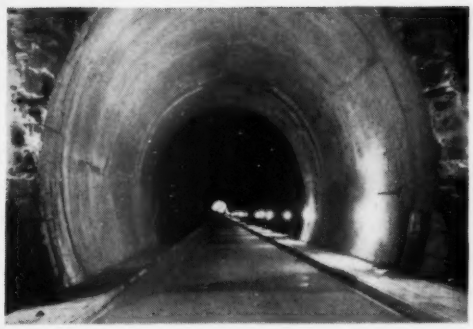

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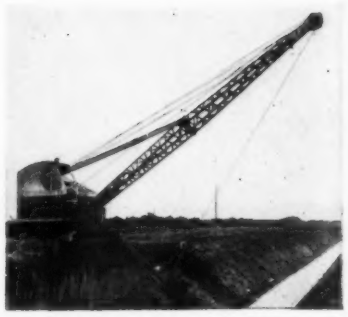

10-RB ¾ cu.yd. dragline dyke-cleaning in the Fens

30-RB 1 cu. yd. shovel loading rock in a road stone quarry

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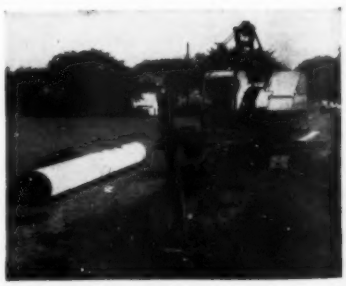

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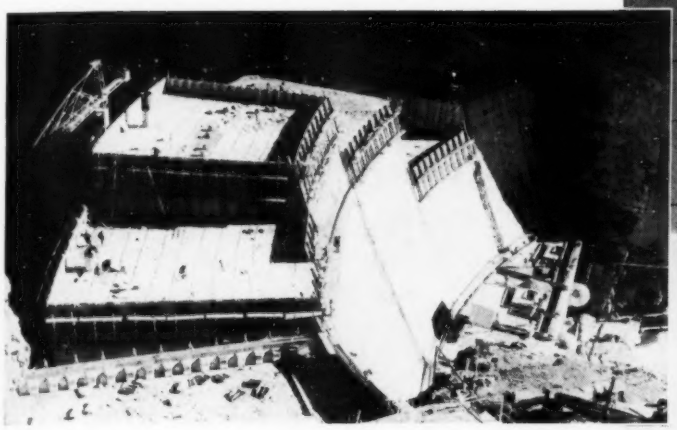
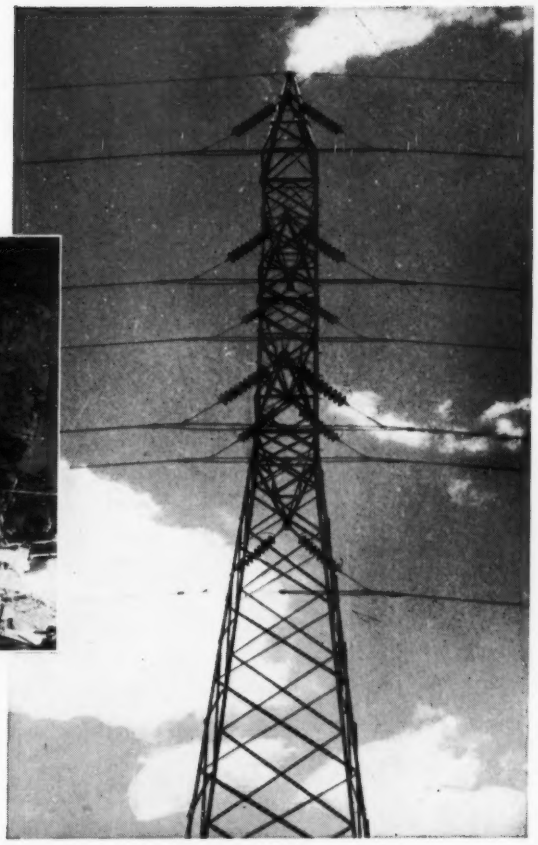
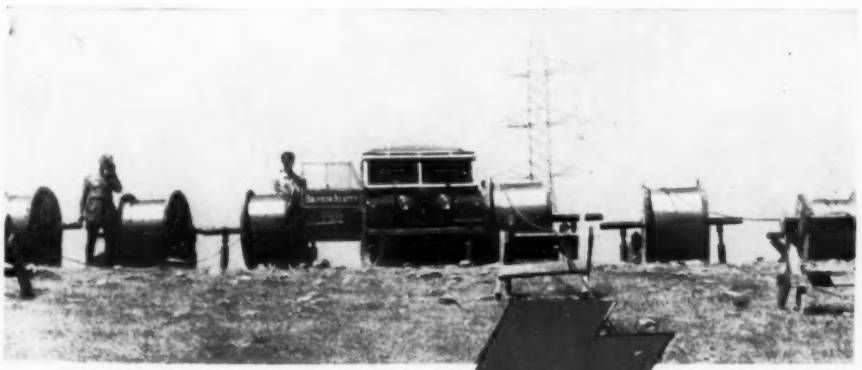


Dokan Dam, harnessing the Lesser Zab River



IRAQ CHOOSES FERAL CABLE

Historically, Iraq, the home of great civilizations, was one of the world's most fertile areas. But for over half a millenium its fertility, dependent on irrigation, has been largely dormant. To restore it and modernize their country generally, the people of Iraq are now using their considerable oil revenues for extensive irrigation projects—which also provide a means of flood control and of generating electric power. Prominent in this development is Northern Iraq, with large dam projects at Dokan and Derbendi Khan. And to supply burgeoning Mosul, Kirkuk, and other northern cities, power is being carried from the new Dibis thermal station on transmission lines equipped with FERAL CABLE — *reliable* Swedish ACSR.



Dusty ground of Northern Iraq calls for cables with close, even stranding in each layer. For the power lines of the new 132,000-volt system, Svenska Metallverken has supplied some 1,400 miles of steel-cored aluminium conductor.

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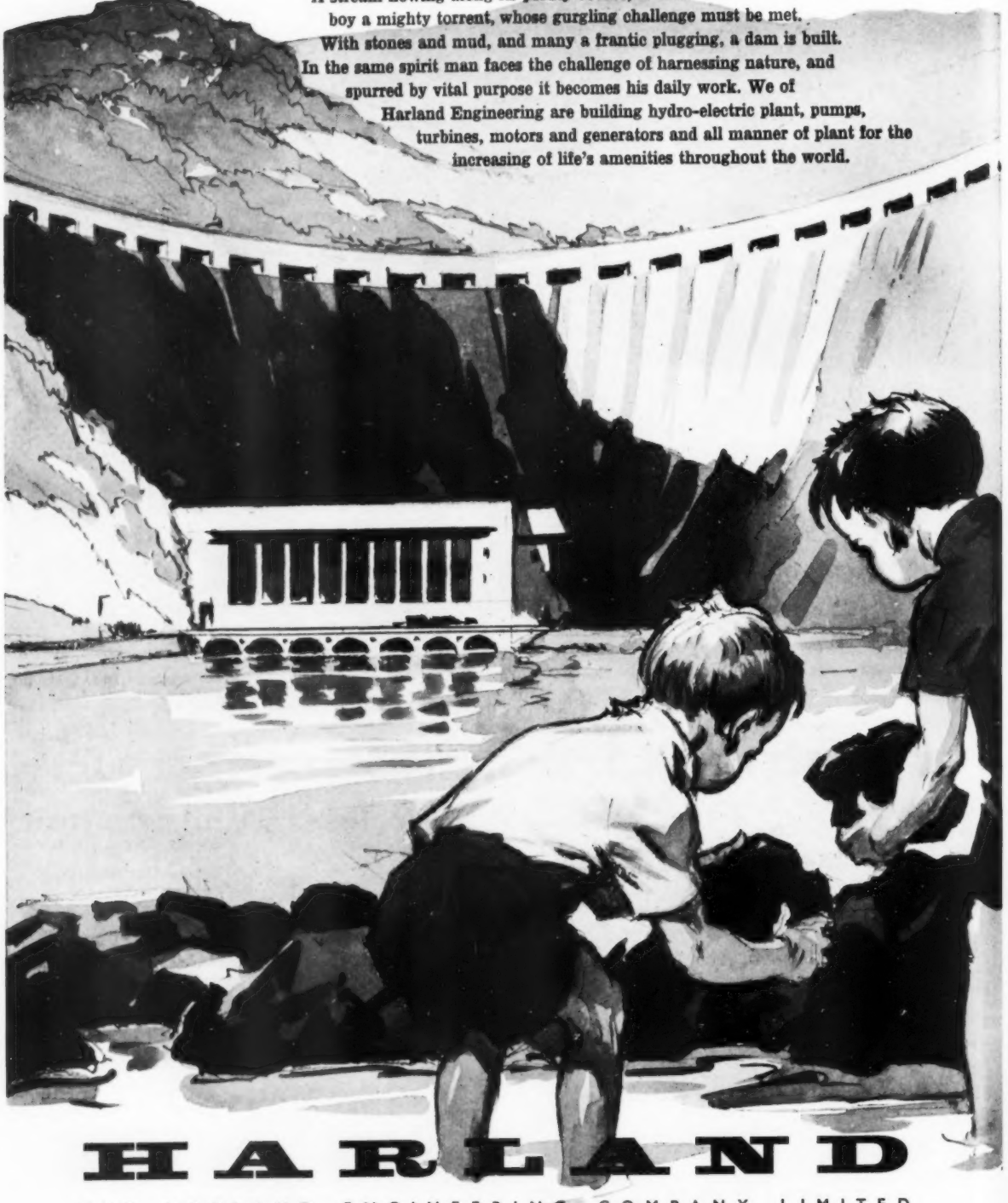

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New power for a Dominion from the Roxburgh Hydro-Electric Project

New Zealand's largest hydro-electrical undertaking, the Roxburgh project, will eventually feed an additional 320,000 kilowatts of electricity into the South Island grid system. The 1,200 ft. Dam, which is the largest ever built in the Dominion, was completed far ahead of schedule by Cubitts' New Zealand Co., in association with Conrad Zschokke Ltd., Geneva, and Downer & Co. Ltd., New Zealand.

This is one of many examples where the experience of the Cubitt Group of Companies is helping in the development of overseas territories.

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WATER POWER

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A Team Effort on Flow Measurement

WATER-FLOW measurements form an essential part of turbine-efficiency tests, and there has always been considerable doubt as to which of the many methods in existence is the most reliable. Some methods are well established, others have yet to be perfected or await recognition, but if a standard procedure is to be adopted a great variety of factors must be considered. The principal requirement of any flow measurement is accuracy, but physical conditions are rarely similar and a method that has proved satisfactory in a laboratory may not necessarily be practicable or efficient in the field. Various methods have been developed and adopted in different countries; for instance, the Allen salt-velocity and the Gibson methods are largely used in North America whereas current meters have been particularly favoured in Europe. There has long been a need for a comparative study to establish which, if any, of the methods in common use can be applied accurately for measurements under all conditions.

Despite the considerable practical difficulties involved, a series of tests using seven different methods was carried out in Scotland on September 9 and 10, 1958. The site chosen was the Finlarig power staion, near Killin, Perthshire, which forms part of the Breadalbane development. Finlarig is principally a peak-load power station equipped with one 30 MW Pelton turbo-generator operating at 375 r.p.m. under a net head of 1,275 ft. The portal valve house, the penstock and the power station itself are all readily accessible and it was therefore comparatively easy to transport the personnel and equipment to the various testing points. By arrangement with the North of Scotland Hydro-Electric Board, who placed the station at the disposal of the team, the flow-measurement programme was timed to take place just before the official acceptance tests, based on the tailrace weir readings, which were carried out on September 11 and 12.

The variety of operating conditions and methods made a central control point essential, and this was installed in the power station, the Chief of Test co-ordinating the activities by telephone to each of the testing stations distributed along the penstock, in the power station, and at the tailrace weir. The testing stations, at each of which a different method was applied, were controlled and manned by independent teams from the different organisations and companies participating in the programme.

The following methods were used at Finlarig: Salt dilution; Gibson; Pitometer; Allen salt velocity; current meter. In addition, thermodynamic measurements of turbine efficiency and tailrace weir readings were also taken as a useful verification of the other results obtained. Before the tests began, it was agreed that measurements should be based on the turbine spear setting rather than on loads and that a test should be carried out at each 10 per cent. stage of spear opening. However, the load permissible in relation to the normal operation of the system was the deciding factor in determining the percentage at any particular time, and although the full range of spear settings was covered, the measurements were not taken consecutively. It was found possible, without causing undue delay, to reduce fluctuations of flow to a satisfactory value and as soon as the flow was steady within the agreed limits after each spear movement, the Chief of Test informed all those concerned that testing could commence. The Gibson test, which requires load rejection, could only be applied when all the other tests had finished, three rejections being made at each load.

The tests were carried out under the aegis of the British Standards Institution, a Technical Commit-

tee of which is in process of producing a new British Standard for the Testing of Water Turbines. A team was constituted for the purpose, largely consisting of representatives of organisations and firms which are members of the Technical Committee. Messrs. Merz. and McLellan, consulting electrical and mechanical engineers for the Breadalbane development, planned and co-ordinated the tests and provided the Chief of Test. During the preliminary work at site and during the tests they were assisted by Messrs. Kennedy and Donkin. The equipment and staff to carry out the flow measurements were loaned by the Mechanical Engineering Research Laboratory, English Electric Co. Ltd., Boving and Co. Ltd., Glasgow University and Lea Recorder Co. Ltd., each undertaking one or more method of testing. The British Thomson-Houston Co. Ltd. took measurements of generator output throughout the tests. Further flow measurements were carried out under contract by British Pitometer Co. Ltd. Messrs. James Williamson and Partners, consulting civil engineers for the Breadalbane development, arranged and supervised the modifications required in the penstock for insertion of the measuring equipment, the work being carried out under contract by P. & W. McLellan Ltd. The staff of the North of Scotland Hydro-Electric Board gave considerable assistance throughout and provided a comprehensive telephone installation between the various testing stations.

Opportunities rarely occur for simultaneous gauging by various methods and it is therefore interesting to note that careful preliminary preparation and organisation at Finlarig made it possible for everyone concerned to extract the maximum of information under ideal conditions. It will be some time before all the data have been assembled, assessed and compared and it is obviously impossible to attempt an evaluation at this stage. However, whatever the results and conclusions, it is gratifying to know that British engineers have been able to collaborate in an attempt to find the best solution to a major problem in hydraulic engineering.

The World Bank and Hydro Power

SOME idea of the immense help given by the International bank for Reconstruction and Development to hydro-electric development throughout the world can be gained from a perusal of the Bank's Thirteenth Annual Report for the year ended June 30, 1958. During the year 34 loans were made for all purposes to the equivalent of U.S. $711 million, and of this total $242 million was for power development, all but about $54 million of which was for hydro-electric schemes. During the previous year loans for electric power had totalled £108 million out of a total of $388 million.

The largest loan made for power purposes during the year under review was that of $66 million to the Yanhee Electricity Authority of Thailand. The Yanhee project is a multi-purpose one covering power, irrigation and flood control, and the first stage consists of a dam 500 ft. high on the Ping River, a 140 MW power station, and two transmission lines to Bangkok. The ultimate capacity of the scheme is 560 MW.

Three loans were made to Japan, two of them through the Japan Development Bank. One of these, of $37 million, is to finance the 258 MW Kurobe station being built by the Kansai Electric Power Company, and the other, of $25 million, will enable the Hokuriku Electric Power Company to add 261 MW of generating capacity to its installations on the Joganji River. A loan of $7 million has also been advanced to the Aichi Irrigation Public Corporation for a multi-purpose scheme which will include 10 MW of power plant.

In the Philippines a loan of $21 million to the National Power Corporation will assist in the construction of the Binga project in northern Luzon, which will comprise a dam and reservoir on the Agno River, an underground power house of 100 MW capacity, and transmission lines to Manila.

Mexico received two loans, one of $11 million to Mexican Light and Power Co. Ltd. for expansion to its thermal plant, and one of $34 million to the Federal Electricity Commission for the construction of four power stations, totalling 413·6 MW, three of which will be hydro stations.

A loan of $13·4 million to Brazil will enable the State of São Paulo to build an 85 MW station at Jurumirim on the Paranapanema River to supplement the 68 MW Salto Grande plant for which the Bank made a loan in 1953.

Ecuador received a second loan of $5 million towards the construction of the first half of a 40 MW hydro-electric plant and a 6,000 kW diesel plant to supplement the power supply to Quito.

In Austria the Vorarlberger Illwerke has been able to complete its 186 MW pumped-storage station at Lünersee by a loan of DM15 million, equivalent to $3,571,000.

In a reference to progress under earlier loans, the Report refers to two outstanding hydro-electric developments—Kariba, towards which the Bank advanced $80 million, and the Damodar Valley Corporation's developments, for which nine Bank loans totalling more than $300 million have been made.

Since its inception the World Bank has advanced $1,106 million for power development throughout the world out of its grand total of $3,729 million. Although this figure of $1,106 million includes advances for thermal plant it remains a striking commentary on the service the World Bank has rendered, and is rendering, to hydro-electric development.

Cross-Channel Cable-Laying Trials

THE proposal to link the British and French electricity-supply systems by submarine cable has been carried a stage further by carrying out cable-laying trials over part of the route. This link, which it is hoped will be completed in 1960, will make engineering history, for it will utilise direct current at a conductor-to-conductor voltage of 200 kV and will have a capacity of 160 MW. Two single-core cables will be used, operating respectively at plus and minus 100 kV to earth, and to avoid interference with ships' compasses by the magnetic field from these cables it will be necessary to lay them not more than 10 ft. apart in depths up to 18–19 fathoms. To accomplish this special cable-laying gear was designed for the exactly simultaneous laying of the two cables, and was installed for the purpose of the trials in the British Central Electricity Generating Board's collier *Dame Caroline Haslett*.

Actual sea trials began by the simultaneous laying of two 880 yard lengths of cable, an explosive charge was then detonated to sever the cable, the severed ends on each side brought to the surface in turn and two 220 yard lengths of cable jointed in. The distant ends of the original cable were then jointed together to form a loop for electrical tests, and finally the whole of the cable was recovered and subjected to critical tests and physical examination. The trials thus provided valuable guidance as to the techniques of simultaneous cable laying and of subsequent repair as well as on the design of the cables themselves.

Two British companies—British Insulated Callender's Cables Ltd. and Siemens Edison Swan Ltd.—were commissioned to undertake the trials jointly for the Central Electricity Generating Board, and during the trials use was made of a midget submarine supplied by Compagnie pour l'Exploitation Internationale des Procèdes Rebikoff and skin divers of the Société Générale de Travaux Maritimes et Fluviaux to inspect, film and photograph the stages of the underwater operation, and to place the explosive charges. Each of the two British companies manufactured one 880 yard length and one 200 yard length of cable, their respective cables being manufactured to slightly different designs in order to help determine the final design of cable and accessories. The cable conductor is 0·525 sq. in. with impregnated-paper solid-type dielectric to operate at 100 kV d.c. conductor-to-earth. The insulated core is lead sheathed, the lead again being protected from chemical action by an impervious covering and from mechanical damage by heavy galvanised steel wires, with an overall covering of impregnated jute. The overall diameter of the cable is 3·07 in., and the weight 36 lb. per yard.

The British and French sections of the submarine link will meet in roughly mid-Channel, and a similar programme of tests on the French section was scheduled to follow the British tests.

Grouting at Mission Dam

THE 180 ft. high Mission Dam is being built by British Columbia Electric Co. Ltd. on the Bridge River in British Columbia. This river flows through a glacial valley of solid granite which is filled with pervious gravel and sand to a depth of nearly 500 ft. below the present river bed. Although there is a layer of clay lying across the canyon some 20 to 40 ft. below the surface of the gravel and sand deposit, water seeps under the clay layer at points where it is separated from the walls of the canyon by talus or rock spurs.

Normal cement grouting would be useless because the particles of cement are larger than the openings between the particles of sand and gravel which the grout must fill. The French firm of Soletanche is now working at the site and will overcome the grouting problem by using a special grout formula, with a clay base, which was developed in Europe some years ago. The Bridge River project is the first North American site at which this method has been employed.

A 50 ft. thick grout curtain will be injected through 125 holes to a depth of nearly 500 ft. immediately upstream from the dam and a watertight wall of steel pilings will prevent seepage through the gravel between the river bed and the layer of clay.

An interesting feature of this project is the provision made for subsequent settling of the dam into the clay strata. The design incorporates a bulge on the surface of the dam which will flatten when the structure subsides.

Turbines for Karadj

THE water turbines and governors to be installed in the new power station now being constructed in the Elburz Mountains near Teheran, Iran, for the Karadj Dam Authority by Morrison-Knudsen International Constructors, Inc. and their Consulting Engineers, Harza Engineering Company International, are to be built by The Harland Engineering Co. Ltd. at their Alloa Works, Scotland, where recent extensions were made to meet an increased turnover of hydro-electric generating plant. These turbines, of the Harland-Morgan Smith vertical Francis type, will be installed in 1960 and are rated at 56,000 h.p. under 482 ft. net head at 333 r.p.m.; each is capable of producing approximately 80,000 h.p. under maximum head. Special features in the design of the turbines will be made to meet a very wide head range. Power from the station, which is designed to receive three generating sets, will be transmitted to Teheran approximately 29 miles away.

Glen Moriston Power Station

THE Glen Moriston power station, which is the last of the four main units in the Garry and Moriston development, was officially opened by Sir Christopher Hinton on September 27. This underground power station is situated 300 ft. beneath Dundreggan dam and the machinery includes two 18,000 kW vertical shaft Francis turbines. The group control station for Glen Moriston and Glen Garry schemes is at Auchterawe switching station, Fort Augustus. The Moriston development, including the Ceannaeroc and Moriston power stations, has a total catchment of some 158 sq. miles.

Ybbs-Persenbeug North

THE first turbine installed in the northern station of the Ybbs-Persenbeug power station (see WATER POWER, June 1956, page 207) has recently been connected to the Austrian grid, thus increasing the average annual output of this scheme to 850 million kWh. Work has been completed earlier than expected and the original estimate of output for the current year will be exceeded by some 5 million kWh.

This turbine, which weighs 942 tons, has an installed capacity of 32,300 kW and is one of the largest units existing in Europe. The direct-coupled generator has a nominal output of 45,000 kVA and weighs 408 tons.

Helicopter Lift of Steel Pylons

IN New Zealand a helicopter is delivering steel pylons and power transmission cable into a three-mile section of precipitous country near the town of Kaikoura where a 33 kV transmission line is being constructed to give the town a connection with the South Island power system. At present, electricity for Kaikoura is generated in the town by diesel plant.

The helicopter has been carrying sections of steel towers 43 ft. high, together with drums of transmission line from a paddock alongside the Blenheim-Christchurch highway, up to a height of 1,000 ft. It places each "bundle" of 500 lb. gently on the site of each tower. Altogether 24 steel towers are to be delivered by aircraft.

Reservoir Power Station for Victoria

GENERATING plant has been ordered for the new hydro-electric power station which the State Electricity Commission of Victoria, Australia, is to establish, by arrangement with the State Rivers and Water Supply Commission, at Cairn Curran reservoir on the Loddon River at Baringhup, a few miles west of Castlemaine. Announcing the start of work, an S.E.C. official said the plant would be supplied from England by Boving & Co. Ltd. It would be in service early in 1960. The capacity of the power station would be 2,000 kW. Except when starting up and stopping, operation would be entirely automatic.

The new Cairn Curran hydro station would utilise for electricity generation water released from the reservoir for irrigation along the course of the Loddon River. Cairn Curran would be interconnected with other power stations in Victoria's state-wide generating system. It would contribute an average annual output of nearly 4 million kWh to the system, connecting at Castlemaine by a 22 kV power line.

Cairn Curran reservoir was built by the State Rivers and Water Supply Commission and completed late in 1955. It has a water storage capacity of 120,000 acre-ft. The dam is an earthfill type, 120 ft. high at its crest and 2,280 ft. long.

New Barron Falls Station, Queensland

DETAILS of the new 60 MW hydro-electric generating station to be built in the near future at Barron Falls, near Cairns, Northern Queensland, are as follows: Water will be diverted from the Barron River at an existing pondage weir about one quarter of a mile above Barron Falls (i.e. between Kuranda and the falls) through steel-lined tunnels to an underground generating station located under the right bank of the gorge below Robb's Monument and a little upstream from Surprise Creek. At present the crest level of the existing pondage weir is R.L. 1,032 ft. This weir will be raised, the crest level being between R.L. 1,040 and 1,048 ft., depending on the pondage requirements, which have not been finally determined as yet. It will then become the diversion weir. From the intake at the diversion weir a horizontal tunnel about 9 to 10 ft. in diameter will run for 5,370 ft., and a steeply inclined pressure tunnel about 6 to 7 ft. in diameter and about 1,300 ft. long will lead from the horizontal tunnel to the underground generating station.

The finished dimensions of the machine room will depend on the plant chosen, but it is expected to be about 160 ft. long, about 50 ft. wide, and about 60 ft. high above floor level. The basement depth below floor level will be about 50 ft. The floor level will be R.L. 128 ft. As the floor level is below flood level in the gorge, an inclined access tunnel is required for it, the portal level being R.L. 160 ft. There will be a ventilating tunnel also. Two generating sets, each of 30 MW capacity, will be installed in the machine room. It is expected that they will be of the vertical, high-speed, Francis type, the approximate normal gross head being about 940 ft. Probably the machines will be coupled to unit transformers and a double-circuit 132 kV transmission line will carry the energy to Cairns substation about 10 miles away. There will be only a minimum of switchgear at the generating station.

It is intended to build an access road up the Barron River gorge on the left-hand side from the existing road to Kamerunga, with a bridge across the river near Surprise Creek. The access road has not yet been finally surveyed, but it will be about three miles in length.

Most, if not all, of the work involved will be carried out by contract, and public tenders will be invited in due course. It is expected that tenders for the generating plant will be called at an early date.

An underground station at Barron Falls already exists, but it is under the left bank of the gorge almost opposite Barron Falls railway station. It has an installed capacity of only 4,000 kW and operates on a head of about 430 ft.

Power Generation in New Zealand

THE New Zealand Government has recently published a White Paper in which details are given of certain alterations to the power development programme. It is intended to make greater use of hydro and geothermal resources than was originally planned, and although the projected gas-turbine power station at Korokoro, near Wellington, will be abandoned and the Cook Strait power cable scheme is to be postponed, work on the Benmore hydro-electric project will continue. The development, which mainly concerns the North Island, has been planned in two parts; the first covers the increase in power production required between now and 1960 and the second concerns projects which can be undertaken subsequently. An impressive plan to harness hydro potential in the Tongariro district is contained in the White Paper. It contemplates the diversion of additional water into Lake Taupo, thus giving additional power down the Waikato, and the development of power from this water before it reaches Lake Taupo.

Progress on Tavera Dam

PREPARATORY work on the Tavera hydro-electric scheme in the Dominican Republic, which will have a capacity of 40,000 kV and also help to irrigate 75,000 acres of land, is entering its final stages. The Department for Development states that this scheme, which is the first of its kind to be undertaken in the Republic, will markedly increase the prosperity of the country.

Soil and seismological surveys have been carried out on the site and the results are being studied by the Laboratory of Technical Research in Madrid, who are to advise on the most suitable design of dam.

The contract for building the dam and installations has been awarded to two Dominican Republic firms, Concretera Dominicana and Mendoza and Armenteros.

Fig. 1. St. Neots paper mill seen from across the Great Ouse

Water Power for a Paper Mill

An installation in an English paper mill emphasises the value of the small hydro-electric plant and demonstrates in miniature the benefits of a properly planned correlation between hydraulic and thermal sources of power production

IN the study of hydro-electric development it is all too easy to become so preoccupied with the factor of size as to overlook the economic significance of the small water turbine. Nevertheless, as we have pointed out in this journal on several occasions, the small water turbine possesses great potentialities, and, indeed, has a distinctive field of application. For instance, about five years ago the possibilities of "micro" power plants in providing an electricity supply to isolated localities were deemed worthy of study by the United Nations Economic Council on Rural Electrification, and certain manufacturers in England and in some other countries have developed "packaged" units to cater for this market. On a slightly larger scale, there are many sites where a few hundred kilowatts can be had for the cost of development and which could serve a local community more economically than a long transmission line.

Another important field for the small water turbine is in industry. Where a flour, textile or other mill is favourably situated, water power, in many cases, can furnish current at a lower price than that of outside supply, even allowing for the high installation cost usually involved. In many instances the replacement of an old waterwheel by a turbine enables a head to be developed with only a moderate outlay on civil engineering, making the economic comparison even more favourable.

In the planning of large electrical networks a factor that has assumed increasing importance is the correlation of supplies from hydraulic, thermal, and more recently nuclear sources. In some industrial plants there is an interesting parallel to this. The available hydraulic resources may be insufficient to meet the requirements, and thermal plant or public supply may be needed to make up the balance. In many instances process heat is required, and this may favour the use of thermal plant to take part of the load. Then again, just as the ruling conditions in a large network dictate the form of correlation—which may range from thermal base load with hydraulic peaking to hydraulic base load with thermal peaking —so the manner in which a combined industrial power plant is operated depends on the pattern of the demand and of the resources available to meet it.

The considerations we have outlined are admirably

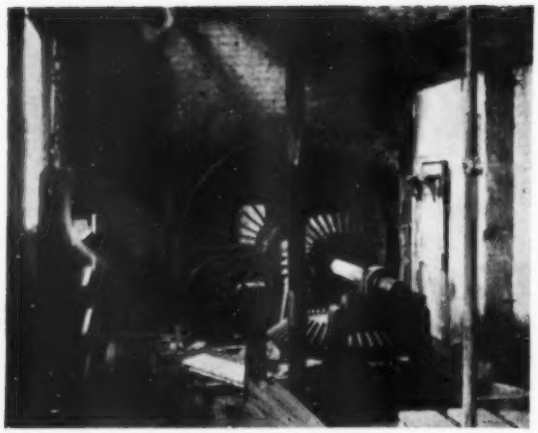

Fig. 2. Mitre gear and belt drive from the old water turbine

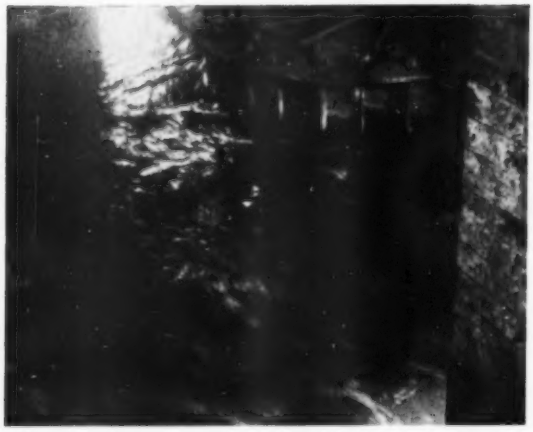

Fig. 3. The old Francis-type turbine shortly before dismantling

demonstrated by the power plant of an English paper mill which we recently visited—the St. Neots mill of Samuel Jones & Co. Ltd. This mill, which stands on an island between two branches of the Great Ouse in Huntingdonshire, has a history as a corn mill going back to the Domesday Book. It was converted to a paper-processing mill in 1799 and was taken over by Samuel Jones & Co. Ltd. in 1950 for the manufacture of gum-coated paper tapes, coated papers, and miscellaneous articles such as lace paper doyleys and cake cups, under their well-known trade mark the Camberwell Beauty Butterfly. Since acquiring the mill, Samuel Jones & Co. Ltd. have made important extensions to the premises and radical alterations to the factory equipment, and this has involved a complete reorganisation of the power services.

Three-shift working is in force, the normal load during the morning and afternoon shifts being of the order of 220 kW and during the night shift 50 kW, the total weekly consumption being about 18,000 kWh. Contemplated extensions to the mill would greatly increase these figures. As will have been gathered, the mill does not manufacture its own paper, so there is not the heavy demand for process steam that obtains for papermaking, but about 12,000 lb. of steam per hour is required for vat heating, glue drying and similar purposes, to which is added about 4,500 lb. per hour for factory heating in winter.

The old power plant dated back to the early 1900's, and included three 11,000 lb. per hour Lancashire boilers providing the necessary heating steam and also supplying a 250 b.h.p. Belliss & Morcom two-cylinder vertical condensing steam engine driving a d.c. generator. There was also an old water turbine driving a second d.c. generator. This turbine, which was of the open-flume vertical Francis type, was connected to the generator through a pair of cast-iron mitre wheels and a belt drive. Photographs of the turbine and the drive, taken just before dismantling, are reproduced in Figs. 2 and 3, and of the Belliss engine in Fig. 12.

When it became evident that the existing power services were quite inadequate to meet the needs of the mill, Samuel Jones & Co. Ltd. engaged Griffin, Smith & Partners as Consulting Engineers to draw up a reorganisation scheme in collaboration with Mr. Kenneth Wood, the Chief Engineer of the mill, and to superintend the design and reconstruction. C. Lovett Gill & Partners were retained as architects.

The scheme envisaged the replacement of the old water turbine, which was in a very unsatisfactory condition, by an entirely new water-turbine installation designed to make the fullest economic use of the river flow at the mill and to furnish base-load power. Power required beyond the capacity of this installation would be supplied by diesel engines, and future mill extensions would be catered for by corresponding additions to the diesel plant. The mill electricity supply was to be changed over to alternating current, and speed control, where necessary, obtained by the use of a.c. commutator motors. This scheme was duly carried out, and we propose to describe it and to give a brief account of its operation.

The boilers were perfectly sound and have been

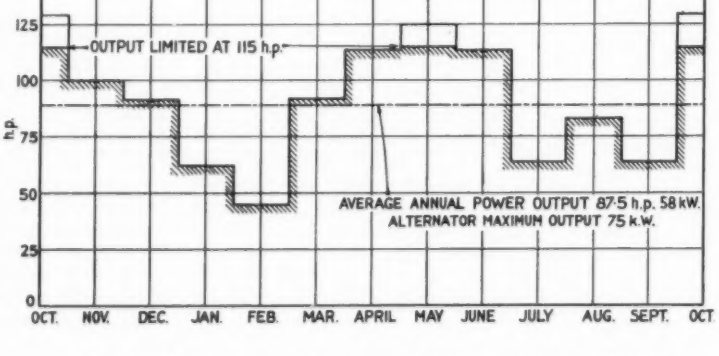

Fig. 4. Chart of monthly average power output available

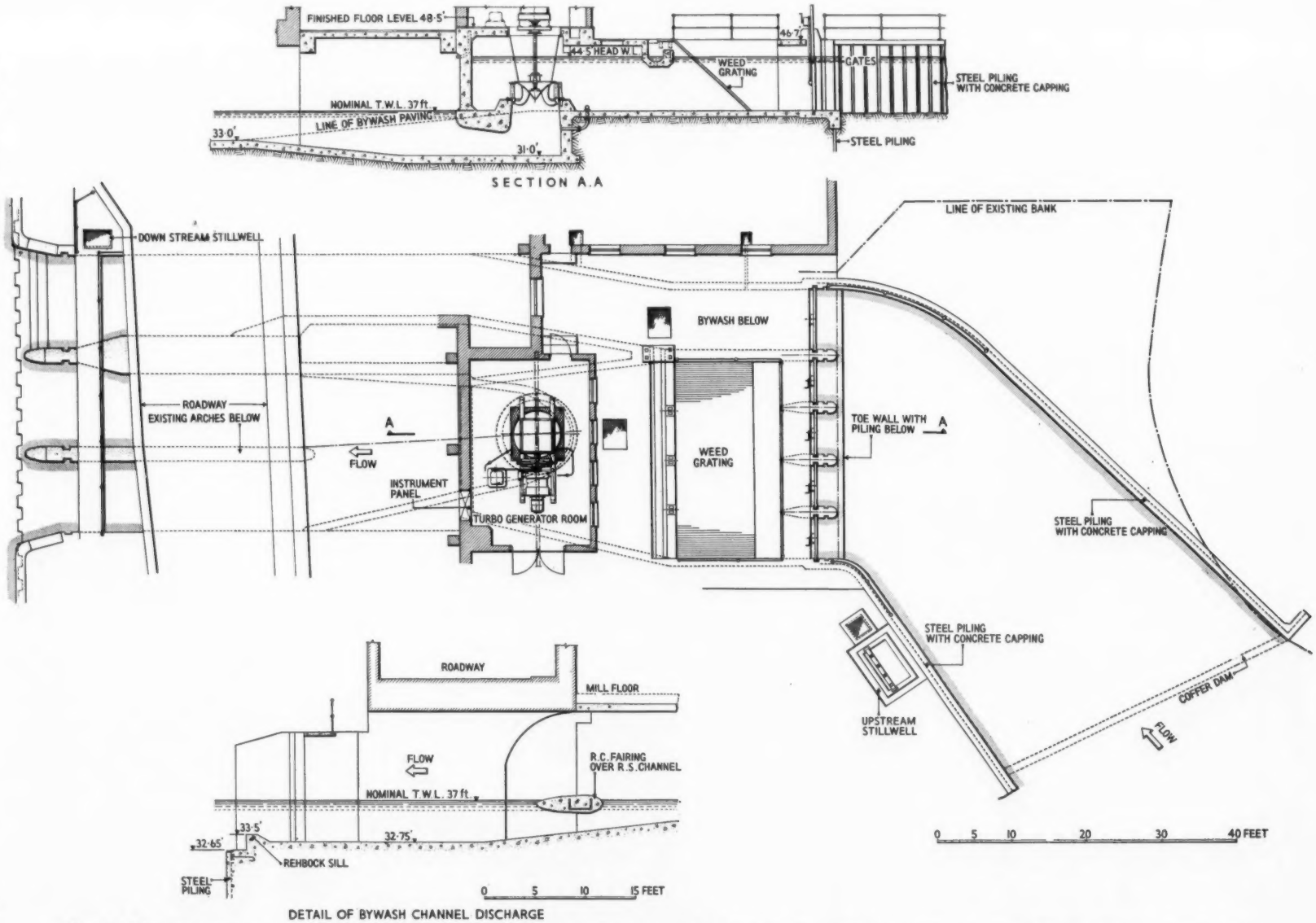

Fig. 5. Plan and sectional elevations of the civil engineering for the hydro-electric plant at the St. Neots paper mill of Samuel Jones & Co. Ltd.

retained, but they have been improved by the substitution of Oldbury forced-draught chain-grate stokers for the original hand-fired furnaces. Steam is generated at 140 lb. per sq. in. and superheated to 550°F.

Also, the Belliss engine, which was in excellent condition, was retained, primarily as a standby unit, but in conformity with the policy of changing the electricity supply over to alternating current the old d.c. generator was removed in favour of a Lancashire Dynamo & Crypto 150 kW 415 V 428 r.p.m. alternator.

Hydraulic Survey

As a preliminary to making any firm proposals, the consulting engineers carried out a water-power survey of the site based on monthly figures furnished by the Great Ouse River Board for the period October 1937 to September 1945. Over this period the monthly average flow was found to range between 1,400 and 98 cusecs. Figures were not available to show the correlation between flow and available head at the site, but observations showed that at low flows the head was about 8 ft. and that it varied more or less inversely with the flow because of the rise in tailwater level. Calculations were therefore based on a head of 7 ft. 6 in. at a flow of 100 cusecs, reducing to 4 ft. at 1,500 cusecs, and the curve reproduced in Fig. 4 was developed to show the monthly average power output obtainable.

From the shape of this curve it is evident that the output could be provided most efficiently by installing two machines, but this was ruled out by the capital cost involved, and proposals were made on the basis of a single machine. To accept the monthly average peak of 127 h.p. would have entailed installing an 84 kW set, providing an average annual capacity of 59 kW, but it was considered to be more economic to limit the peak to 115 h.p., enabling a 75 kW alternator to be used. A machine of this size would provide an average annual capacity of 58 kW—a sacrifice of only 1 kW. On this basis it would be possible to generate 506,000 kWh per annum from the available flow at the site. The actual plant was designed in accordance with this recommendation.

Turbo-Alternator

The turbine was built by The Armfield Hydraulic Engineering Co. Ltd., Ringwood, Hants., and a sectional elevation of the set is given in Fig. 6. It is rated at 108 h.p. at a head of 6·5 ft. and a speed of 83·5 r.p.m., and is set for a maximum output of 120 h.p. The runner is of the Francis type, 48 in. in diameter and having a specific speed of 85 (British units).

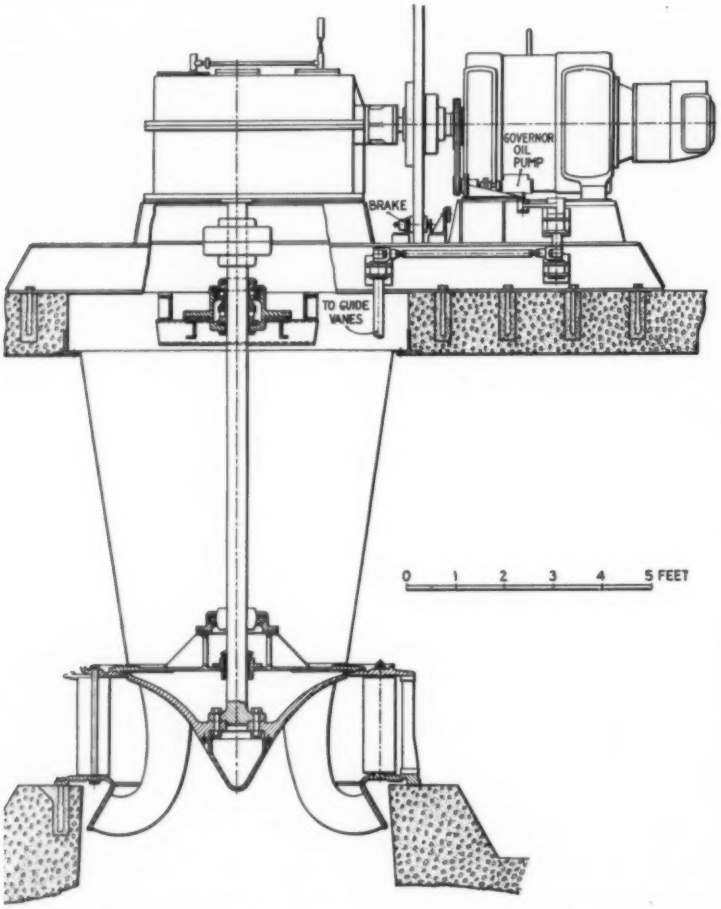

Fig. 6. Sectional elevation of the Armfield 120 h.p. open-flume Francis turbine

Owing to the low head and the consequent large water volume involved, the most economical design was an open-flume type of machine. The shape of the chamber will be seen in the civil-engineering drawing, Fig. 5, and it will be noticed that the turbine is mounted on a plinth to improve the water flow and to act as a stone trap. The guide-vane assembly is mounted on this plinth and is controlled by a vertical spindle actuated by the governor unit on the generator floor. All underwater parts of the guide-vane control linkage are made of corrosion-resisting materials and are fitted with water-lubricated bushes.

The runner and shaft are suspended from a bearing assembly at generator floor level consisting of a ball journal and a self-aligning ball thrust bearing, which accepts the hydraulic thrust as well as the suspended weight. Mounted on the turbine cover immediately above the main shaft gland is a split roller guide bearing. Both bearing assemblies are grease lubricated. A fabricated steel cone fitted between the structure at generator floor level and the turbine cover excludes water from the shaft and bearings and allows access from the turbine

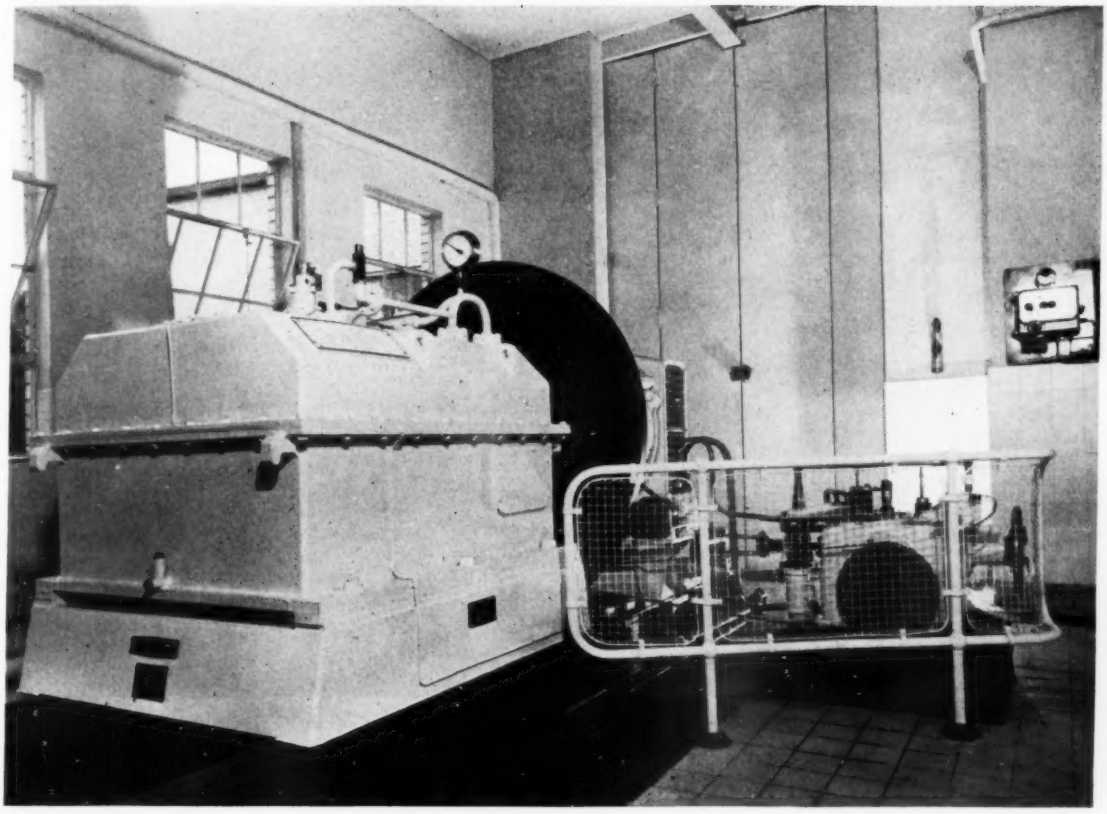

Fig. 7. Generator floor of the Armfield/L.D.C. 75 kW turbo-alternator. The David Brown 83·5/750 r.p.m. gearbox is on the left and the governor unit on the right

house for inspection and maintenance purposes.

A David Brown two-stage speed-increasing gear is mounted above the turbine, providing a right-angled drive to a horizontal generator running at 750 r.p.m. A flywheel is interposed between the gearbox and the generator to assist parallel running, and a hand-operated brake is provided to engage the faces of this flywheel when bringing the machine to rest.

The governor is belt driven from the generator shaft, and is supplied with pressure oil by a positive-displacement pump also driven from this shaft through a double vee-belt. Adjustments are provided for running speed, speed droop, and maximum gate opening. A speeder-gear motor is coupled to the running-speed adjustment and can be controlled by push-buttons either from the local turbine instrument panel or from the main switchboard in the diesel power station, to be described later.

A Lancashire Dynamo & Crypto alternator with overhung exciter is driven from the high-speed shaft of the speed-increasing gear. It is rated at 75 kW 415 V 0·8 p.f. 50 c.p.s. Turbine, speed-increasing gear, flywheel and alternator are designed to withstand a maintained overspeed of 85%.

In the view of the turbine-house generator floor, given in Fig. 7, the speed-increasing gear can be seen on the left and the governor unit on the right. The generator is largely obscured by the flywheel, to be seen behind the gearbox.

Civil Engineering and Water Control

In planning the installation the advantage was presented that the head had already been developed and the intake chamber and tailrace constructed for the previous turbine, but in the event it proved necessary to reconstruct virtually the whole of the civil-engineering work and water-control arrangements from head to tailrace, although the existing channel was used. The plan and section reproduced in Fig. 5 show the major part of this work, although there was some additional embankment work outside the limits of these drawings.

The intake channel was entirely remodelled to afford a smooth entry, using interlocking steel piling surmounted by concrete capping. The turbine headrace, flume chamber and tailrace were all reconstructed in reinforced concrete, and the arches of a road bridge through which the tailwater discharged were reinforced and gunited.

The three old headgates were replaced by four Armfield sliding-type gates, each 5 ft. 6 in. wide by 7 ft. 9 in. high and hand operated through a David Brown Radicon worm gear. In the headrace behind these gates is an inclined weed grating with power-operated rakes.

The headrace and tailrace levels are detected by air pressure and are measured by two Evershed & Vignoles electronic repeater pressure transmitters. These pressure measurements, translated into feet of head,

Fig. 8. Armfield intake sluices and bywash control gate (right). The top of the upstream stillwell is on the extreme left, and the turbo-alternator house is the low central building

are indicated in the turbine house, the power house, and the watchman's office.

It is a requirement of the Great Ouse River Board that the river level upstream of the mill shall be maintained within a range of 6 in. To meet this condition a bywash channel (see Fig. 5) was constructed to the right of the turbine flume and controlled by an automatic bywash gate. This gate, also supplied by The Armfield Hydraulic Engineering Co. Ltd., is 8 ft. wide by 7 ft. 9 in. high, and is of the fixed-roller type with renewable rubber seals. It is operated by a ½ h.p. L.D.C. geared motor through a David Brown Radicon worm gear, giving a total reduction of 3420 : 1, and is controlled by two pairs of Evershed & Vignoles No-Flote electrodes in a stillwell alongside the headrace. A Venner time switch energises the control circuit for two minutes in every twenty, during which time the gate can travel 15 in. According to the Chief Engineer of the mill, this control has actually been found to regulate the upstream river level within about two inches. Pushbutton control of the gate can also be effected either locally or from the turbine house.

The bywash channel is carried below the mill building and discharges through an arch under the road bridge adjacent to the two arches spanning the tailrace. Unfortunately a channel-section beam forming an essential part of the structure of the mill building spanned the proposed bywash channel below water level and it was not feasible to remove it, but the difficulty was surmounted by moulding a reinforced-concrete streamlined fairing round the beam, as shown in Fig. 5. During the site investigations it was found that the previous installation had caused severe scouring of the river below the tailrace, and to prevent the high-velocity discharge from the bywash channel from aggravating the trouble a Rehbock sill, also to be seen in Fig. 5, was formed on the discharge lip of the channel. This sill proved so effective that not only did scouring not occur but the hole in the river bed filled itself up.

The intake and tailrace appear in Figs. 8 and 9.

Fig. 9. A view of the reconstructed tailrace

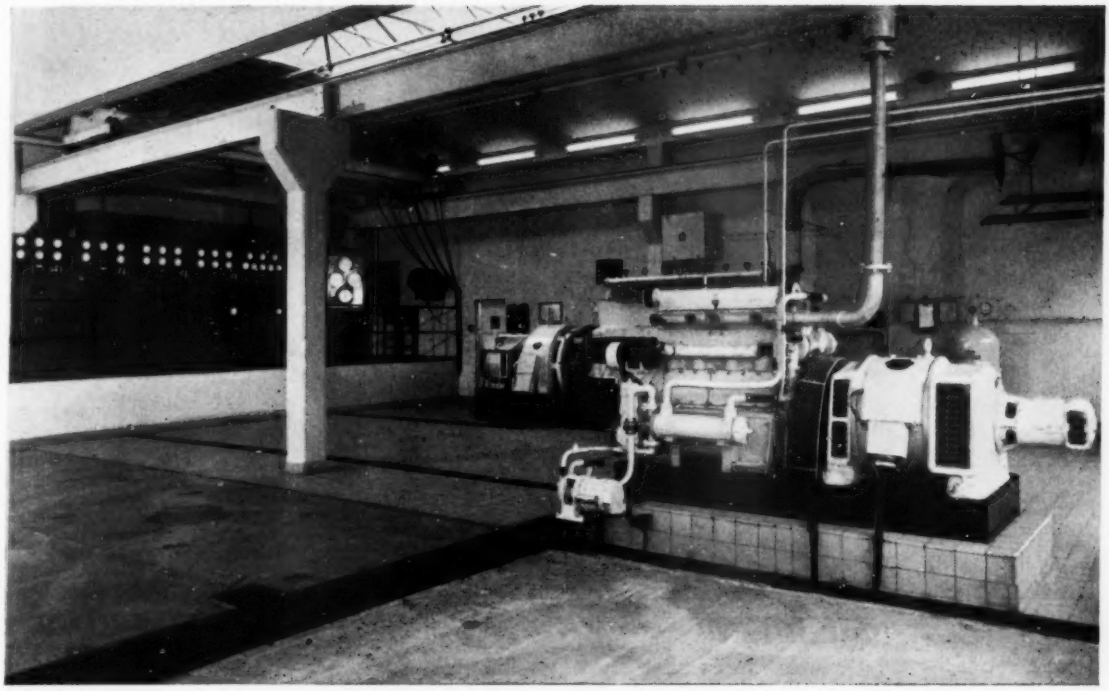

Fig. 10. The new diesel power house and main control board

Diesel Plant

The diesel power plant is installed in a new main power house depicted in Fig. 10, which also contains the main switchboard. It is just across the yard from the water-turbine house.

The main diesel-alternator set consists of an eight-cylinder Lister-Blackstone vertical diesel engine developing 300 b.h.p. at 500 r.p.m. and direct coupled to a 200 kW Lancashire Dynamo & Crypto alternator. This set is placed on anti-vibration mountings and is not bolted down. The exhaust is passed through a waste-heat boiler which supplies factory heating during the winter, but in summer the boiler is run dry and acts merely as a silencer.

Space has been provided in the power house for three similar sets when required.

A house set has also been installed, consisting of a Paxman-Ricardo four-cylinder diesel engine developing 80 h.p. at 1,000 r.p.m. and driving a 48 kW Lancashire Dynamo & Crypto alternator.

Electrical System

The electrical system had to be planned to meet certain fairly exacting conditions. In the first place it had to be possible for alternators driven by three types of prime mover—water turbine, steam engine, and diesel engines—to run satisfactorily in parallel. Secondly, some of the mill machines require exact speed regulation, so precise control was needed over both voltage and frequency. Thirdly, the system had to be arranged for easy extension to keep pace with the anticipated growth of the mill.

To secure satisfactory parallel running, together with the steadiness of speed necessary for the fine control of frequency, great attention was paid by the consulting engineers to all generator characteristics, and to the flywheel effects and governor characteristics of the water-turbine and diesel sets, with eminently successful results. Modifications to the governor of the steam engine were considered but were regarded as unnecessary as this set is now reserved for standby and occasional night duty.

Voltage and power-factor control is obtained by a specially designed electronic regulator for each machine, supplied by Lancashire Dynamo Electronic Products Limited, and on the synchronising panel on the main switchboard is mounted an Elliott-Shotter frequency indicator reading to one tenth of a cycle between the frequencies of 48 and 52 c.p.s. The indications of this instrument and of the busbar voltmeter are repeated in the Chief Electrical Engineer's office.

Facilities for future extension are implicit in the design of the main switchboard, depicted in Fig. 11, which was built by the Power Equipment Co. Ltd., Colindale, London. It is of the cubicle type, each cubicle being a self-contained unit so that the various cubicles can be moved and reconnected in any order, and additional cubicles can be inserted as and where required.

At present the board comprises six main panels and a hinged synchronising panel, four of the main panels being for the generators and the remaining two for feeders. All six panels are equipped with Whipp & Bourne airbreak circuit breakers with over-current protection and with Ferranti earth-leakage relays. Each generator panel carries speeder-gear buttons, a voltage-regulator unit, an hours-run totaliser, and a G.E.C. reverse-power relay, as well as the normal field controls, synchronising plug, and instruments. The main mill feeder is rated at 800 A and leads to a main distribution board, supplied by Lancashire Dynamo Switchgear Limited, in a separate room. The remain-

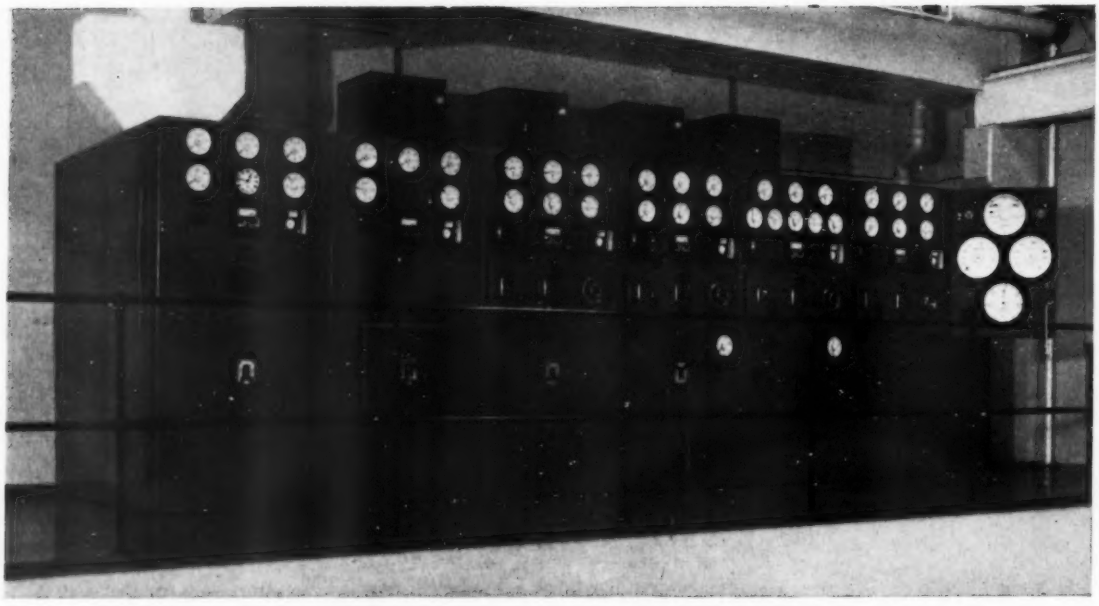

Fig. 11. A closer view of the main control board

ing feeder, rated at 200 A, supplies an essential-service distribution board feeding the power-house and boiler-house services, water and sewage pumps, and emergency lighting. There is also a 24 V battery serving an emergency lighting system which switches in automatically in the event of failure of the main supply. All switchboard instruments, other than those already specifically mentioned, were supplied by the Record Electrical Co. Ltd.

Operation

Considerable interest attaches to the manner in which this combined plant is operated and to the results obtained.

The water turbine runs unattended and continuously day and night, meeting the factory base load and making the fullest possible use of the available water. During the morning and afternoon shifts the balance of the load is met by the 200 kW diesel generator, but during the night shift the main power house is shut down and the load is normally taken entirely by the water turbine. Should the water available be insufficient for the load, the turbine is supplemented by the Belliss steam engine. This engine is adjacent to the boiler house, which has to be operated on all shifts to provide process steam, and can be started by the boiler-house attendant. On the rare occasions when it is desired to shut down the turbine for inspection, its duty is taken over by the 48 kW diesel set.

At the present weekly overall mill consumption of about 18,000 kWh the water-turbine plant is producing power at a cost of 0·6d. per kWh, including all capital charges, depreciation, running and labour costs. On the same basis the cost per unit from the diesel power plant is 1·25d. and from the Belliss set 2d. The overall cost per unit from the combined plant is 1·94d., which compares very favourably with the overall rate of 2·25d. now in force in the area for public supply for industrial purposes.

Acknowledgments

We are happy to record our indebtedness to the directors of Samuel Jones & Co. Ltd. for their kind permission to visit St. Neots mill and to publish this article, and in particular we should like to acknowledge the courtesy of Mr. Peter Jenkin, the Works Manager, and of Mr. Kenneth Wood, the Chief Engineer. We also received valuable information and assistance from Messrs. Griffin, Smith & Partners, London, W.1, the Consulting Engineers, and from The Armfield Hydraulic Engineering Co. Ltd.

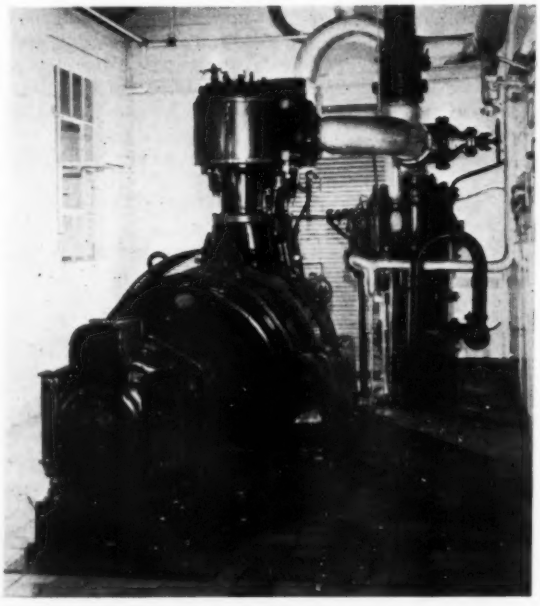

Fig. 12. The standby Belliss steam engine and its associated condenser

Conference on Turbines and Pumps

The Fifth Hydraulic Conference organised by the Société Hydrotechnique de France was devoted to turbines and pumps. In this series of articles we review some of the information likely to be of value to the designer and operator, particularly that relating to materials of construction

PART TWO

METALLURGICAL DEVELOPMENTS

Kermabon & Mosse's paper on operating experience with alloys and cladding, accompanied by tabulated properties (Table VIII) forms a good starting point for examination of metallurgical developments. After stresing the economic loss from lowered efficiency and increased outage time due to progressive wear, the paper concentrates on material behaviour as distinct from hydraulic considerations. This forms a guide to metallurgical requirements in terms of:—

(i) Cavitation.
(ii) Abrasion in:
  (a) Francis runner blades or Pelton buckets.
  (b) Fixed and moving parts of labyrinths.
(iii) Cracking due to metallurgical defects caused by:
  (a) Fatigue with or without corrosion.
  (b) Internal stresses.
(iv) Wear by friction between metallic surfaces.

In connection with cast iron they refer to the results awaited from abrasion-resistance tests on Francis-turbine guide vanes constructed of spheroidal cast iron.

Stainless steels

Colombier & Hochmann's paper examines stainless steels for turbine-runner construction where, apart from operating stresses, high ultimate strength and elastic limits, resistance to mechanical fatigue, cavitation and abrasion must be coupled with easy castability and weldability for site repairs which are primarily metallurgical problems.

For some applications the fatigue strength of modern steels is insufficient and they recall that while progress is needed in this field,

(i) Fatigue strength seldom exceeds 50% of the tensile strength, particularly in cast steel, and may be further reduced by corrosion. Cracks in the splitters, outcuts and fixing of Pelton buckets are typical of such failures. High ultimate strength, elastic limit and ductility are necessary to prevent crack propagation.

Kermabon & Mosse refer particularly to Pelton runners subjected to continuously alternating forces superimposed on centrifugal stresses which demands high fatigue strength. The hydrodynamic shape leads to a heterogeneous stress distribution and highly stressed edges and ribs where frequent checks for metallurgical or mechanical defects and cracks are essential.

For Francis turbines, runner fatigue is less important, because the torque is more nearly constant.

(ii) Cavitation is accelerated by corrosion and nickel increases the resistance and hardness to a limited extent as shown by laboratory tests on cast steels:

Steel Quality	*Loss (cu. mm.)*
Ordinary Carbon	62·4
14% Cr.	32·0
18/8 Cr. Ni	8·8

(iii) For abrasion resistance hardness is the dominant requirement.

It is difficult to protect Francis runners simultaneously against abrasion and cavitation since conflicting hardness and ductility qualities are required. The general concensus of opinion seems to be that only operational experience over a period or in another station on the same river can determine characteristic forms of wear against which it is necessary to protect, but:—

(i) *Carbon Steels* are susceptible to cavitation, low fatigue strength in water and inadequate surface hardness which condemns them to rapid abrasion.
(ii) *Manganese and Chromium Alloys* are better but have insufficient mechanical strength and wear rapidly when subject to corrosion.
(iii) *13% Cr. Martensitic Steels with 2% Nickel* have good mechanical characteristics, adequate surface hardness, acceptable cavitation and fair abrasion resistance. Preheating to 300°C. and post-welding heat treatment is, however, required to avoid martensitic formations, high structural and thermal stresses and cracking in the neighbourhood of the welds. This demands dismantling for runner repairs and special furnace equipment.
(iv) *Austenitic 18/8 Cr/Ni Steels* have weak mechanical properties but are readily weldable. They have good chemical resistance and ductility, but mechanical strength, elastic and fatigue limits are lower than 13% Cr. They are difficult to cast in large components but are suitable for cladding surfaces liable to attack.
(v) *Austeno-ferritic Steels.* The ferro-nickel-chrome diagrams for martensite and austenite show that slight changes in composition modify their properties to give the austeno-ferritics which have been under test in 14 Pelton and 24 Francis runners since 1952.

The alpha $\rightleftharpoons$ gamma transformation plays a predominating role in the characteristics of ferrous alloys and briefly the structure provides equilibrium between elements at normal temperatures to give homogeneous centredfaced cubic crystalline structures with.

(i) Carbon, manganese or nickel in the gamma phase to form and stabilise the austenite.
(ii) Chrome, silicon and molybdenum in the alpha phase forming ferrite.

TABLE VIII. PROPERTIES OF STEELS USED IN TURBINE CONSTRUCTION

Material	Chemical Analysis %										Mechanical Characteristics						
	Mex. C	Cr	Ni	Mn	Mo	Cu	W	Va	Al	Fe	*R* kg/sq.mm.	*E*	*A*%	*KUF* kg.m/sq.cm.	Fatigue kg/sq.mm. Air	Fresh Water	Sea Water
Carbon Steel Weldable	0·2	—	—	0·5	—	—	—	—	—	—	48	24	18	5	24	18	—
Sulphur and Phosphorus Less Than 0·05% Silicon 0·40%	—	—	—	1·2	—	—	—	—	—	—	58	36	26	7	—	—	—
Lightly Alloyed Ni/Mo Steel	0·25	—	2·0	0·7 1·0	0·3	—	—	—	—	—	60 70	35 44	14 18	8 14	—	—	—
Chrome and Chrome Nickel Steels—																	
Martensitic 13% Cast Cr Steel	0·15	12 13	1·5	0·5	—	—	—	—	—	—	65 75	45 53	14 18	3 7	24 27	20 24	7
13% Forged Cr Steel	1·5 2·0	13	—	—	—	—	—	—	—	—	200 220	—	—	—	—	—	—
Austenitic—																	
18/8 Cr Ni Mo Weld Metal	0·1	18 20	8 10	—	2·0 3·5	—	—	—	—	—	65 70	40 45	30	—	—	—	—
18/8 Cr Ni Mo Plate	0·1	17	12	—	2·0 2·5	—	—	—	—	—	55 70	25	40	—	—	—	—
Austeno-Ferritic Cr Ni *Steels*—																	
20/8 Castings	0·12	19·5 20·5	7·5 8·0	—	2·0	—	—	—	—	—	65 70	40 45	20	6 12	17	15	—
20/8 Castings	0·15	20	8·0	0·6	2·5	1·5	—	—	—	—	65	40	—	—	—	—	—
20/4 Castings	0·12	20	4	—	—	1·5	—	—	—	—	65 70	40 45	15 25	5 8	—	—	—
20/4 Castings	0·15	20	3·5	3·0	—	1·5	—	—	—	—	65	40	—	—	—	—	—
17/4 Cr Ni Cu Structurally Hardened Martensitic Steel	0·05 0·12	17 16	4·0 3·0	— —	— —	4·0 2·0	— —	— —	— —	— —	75 85 90	55 60 60	15 —	5 —	32 —	23 —	10 —
Cast Cupro-Aluminium Alloy	—	—	4·5	0·5	—	—	—	—	9·7	2·8	55 65	23 30	12 18	3 5	18	—	14
High-speed Forged Tungsten Steels	0·8 —	4·5 —	— —	— —	0·7 1·5	— —	18 12	1·3 1·5	— —	— —	62/63 Rockwell Hardness 62/63 Rockwell Hardness						

The austeno-ferritic 20/8 Cr Ni steels reconcile some of the contradictory requirements, but their low fatigue strength limits their use to lightly stressed runners.

Moreover, they:—

(a) Give clean castings with a slight addition of molybdenum, but foundry difficulties arise because of the narrow analysis and equilibrium control between the alpha and gamma phases where there is a risk of sigma-phase formation.

(b) May have abrasion resistance increased by the shock of solid particles but this has to be confirmed by experience.

(c) Can be repaired by welding without special precautions, preheating or post-welding heat treatment. By using welding electrodes of suitable composition the same structure and mechanical characteristics in the weld metal, heat-affected zone and parent metal can be obtained, which makes site welding easy.

(vi) *Structurally Hardened 16/4 Martensitic Steels* seem suitable for Pelton runners but their service performance has yet to be proved. 13% Cr. and the austeno-ferritics have low sea-water corrosion and fatigue resistance. A new solution is being sought in the high-chromium martensitic steels with the addition of nickel and copper, which give good properties in sea water but demand the same welding precautions as 13% Cr.

FOUNDRY PRACTICE

While all these steels are clearly dependent on foundry technique for high-quality castings, only one paper, by Privat, is devoted exclusively to it. With chromium alloys, carbon content must be kept low to avoid carbide precipitation at the grain joints which causes intergranular corrosion.

Colombier & Hochmann mention the addition of molybdenum for clean castings and refer briefly to the furnaces and controls for the austeno-ferritic steels where composition must be maintained within narrow limits so that alpha and gamma-phase equilibrium gives the right proportion of austenite and ferrite. If the latter is:—

(a) Excessive, there is a risk of fragility by formation of an intermetallic sigma iron-chromium phase during cooling.

(b) Insufficient, mechanical characteristics will be poor.

Other papers make reference to:—

(i) The inclusion of fixing elements to reduce oxygen, nitrogen and hydrogen content for large clean castings.

(ii) Hot pouring to utilise the vapour screen between the liquid metal and the atmosphere.

(iii) Metal degasification during fusion under vacuum before casting under an inert gas to avoid oxidation, particularly for easily oxidised alloys such as 13% Cr.

Privat's paper is concerned with basic electric 13% Cr martensitic steel, which was chosen for its cavitation and corrosion resistance where, apart from casting difficulties which were studied by scale models, particular attention was given to sand quality and granulometry, melt condition and control of special additions such as carbon and chromium.

The leading characteristics of the Kaplan blades were:—

(i) Blade Dimensions .. .. 2510 × 3940 mm.
(ii) Thickness Max./Min. .. 350/50 mm.
(iii) Blade Melt/Finished Weight 13/8 tons

(iv) Chemical Analysis

	C	Cr	Mn	Si	S+P
%	0·16	13·0	0·70	0·30	Min.

(v) Homogeneous martinsitic structure heat treated to give the following minimum mechanical characteristics:

Ultimate Strength	60. kg./sq. mm.
Elastic Limit	40 kg./sq. mm.
Elongation	14%
KUF Resilience	4 kg. m./sq. m.

Two problems were involved:—

A. MOULDING

(a) *1 : 5 Scale Model Tests* to study the casting process and metal flows:

(i) The mould was constructed in oiled sand and enclosed in plexiglass.

(ii) The liquid metal was simulated by linseed oil to locate the headers to ensure defect-free discharge edges and the best mould inclination to avoid metal turbulence.

(b) *Constructional Materials.* Silico-argillaceous sand with good refractory properties to prevent sand vitrification, shrinkage and finish defects was used. Chemical analysis, fusion point and granulometry are easily controlled but shrinkage limitation was more difficult because excessive thickness had to be avoided.

B. METALLURGY.

In the casting process the main problems stemmed from:

(i) The precautions to ensure low oxygen and nitrogen content and stabilising of that remaining by energetic fixing elements.

(ii) Elimination of hydrogen.

(iii) Chromium oxidation, particularly in thin and thick sections. This demanded rapid hot casting.

(iv) Heat treatment and internal stress control requiring uniform temperatures throughout the casting core and studies of time and rate of heating and cooling.

The author refers to:—

(a) Stress control by strain gauges or Gunnert apparatus, and,

(b) Magnetic, radiographic and ultrasonic checks on casting quality

which were used, but emphasises that care is necessary in interpretation and application of the results when repairs to defective zones are being considered.

Cupro-aluminium alloys

Metallurgical research and operating experience have led to development of finer-grain structures for mechanical strength, and for all-round performance there seems to be a trend in favour of cupro-aluminium alloys, which are readily cast. The 9% Al alloy is an excellent substitute for steel in terms of mechanical properties and resistance to cracking and is easily:—

(i) Cast cleanly to close dimensions.

(ii) Welded horizontally or on a slight slope.

(iii) Cavitation resistant but less so for abrasion.

Weil-Couly & Kermabon's study of "Alloy Cavitation Damage" is relevant since micrographic examination and the intercrystalline attack mechanism suggest that cavitation resistance is due to:—

(a) High elastic modulus and shock damping qualities.

(b) Crystal structures which resist progressive grain exposure.

High-speed steels

According to Ferry, Willm & Thouvenin, abrasion-resisting high-speed tungsten steels are superior to 13% Cr steels by a quality factor of 4. Kermabon and Mosse report that for Pelton nozzles and needles

dealing with heavily charged water they maintain optimum efficiency from two to ten times longer than 13% Cr 0·2–2% C alloys. Two grades with 62/63 Rockwell hardness are in use.

Grade		*A*	*B*
Tungsten	W	18·0	12·0
Carbon	C	0·8	—
Chromium	Cr	4·5	—
Molybdenum	Mo	0·7	1·5
Vanadium	Va	1·3	1·5

Needles and nozzles surfaces should be mirror polished and because these steels:—

(i) Have low resilience due to great hardness, care must be taken to avoid fracture during erection and needle closure.

(ii) Are not rust resisting, they should not be used where the machines are stopped frequently unless protected by hard 13% Cr 2% C plating.

Protective treatments and processes

Metallic surfaces. Auteserre deals with available materials for turbine components based on experience and practice, operating conditions and costs.

References are also made to:—

(i) Thick electrolytic nickel and chromium plating for components subject to fretting corrosion and wear by abrasion, such as coupling bolts and labyrinths.

(ii) Surface treatment by chromium plating and nitriding where metal-to-metal friction and surfaces of differing hardnesses are concerned.

(iii) Molybdenum bisulphide for dry lubrication.

Kermabon & Mosse refer to protective treatments for important components and their views are summarised below:—

(i) *Overlay Welding.*

(a) For cavitation 18/8 should not be used on light-alloy bases for areas in excess of 200 sq. cm. because hard fragile zones and stresses due to different expansion coefficients are set up.

(b) For abrasion, hard-overlay electrodes are undergoing systematic tests on dynamically stressed runners and unstressed nozzle needles.

(ii) *Cladding* with 3 mm. plates of:

(a) 17% Cr/12% Ni/2% Mo

(b) 9% A_e/4·5% Ni

is more compact and homogeneous than overlaying and less subject to welding stresses and deformation.

(iii) *Metallisation.* Pistol deposition of 1·2% C alloy to resist abrasion needs careful base-metal preparation but gives hard resistant surfaces.

(iv) *Hard Electrolytic Chromium Plating* is particularly suitable for Francis labyrinths where only the fixed part is subject to wear by centrifugal action of sand. It is also applicable to wearing rings, guide vanes and Pelton needles and nozzles, but it should not be deposited on castings, which, apart from their structure, may contain blowholes or inclusions. Forged or plate steel support should be used with:

(a) Carefully finished and preferably polished surfaces.

(b) Minimum Brinell hardnes of 200.

(c) Radiused corners and chamfer edges.

(d) Recommended plating thickness for:

(i) Abrasion .. .. 0·20 mm.

(ii) Severe Abrasion .. 0·40 mm.

(iii) Rubbing Surfaces .. 0·03–0·05 mm.

Plastic and rubber applications. While polyesters and fibre glass are being investigated, tests with plastics and rubber have given varied results. For:—

(a) *Cavitation.* Neoprene has been partially successful.

(b) *Abrasion.* Overall resistance of plastics to abrasion is poor but synthetic rubber for guide-vane bushes has been satisfactory.

(c) *Rubbing Friction.* Lever/link systems, guide-vane spindles and needle/deflector controls with bronze bushes, slow limited movement and grease injection suffer from imperfect lubrication and appreciable wear aggravated by abrasive water. Tests with fritted metals and self-lubricating plastics such as teflon show considerable improvement.

Conclusions

The Fifth Hydraulic Conference has put the metallurgical aspects of turbine operating conditions on a clearer basis than it has been hitherto. The factual operating and metallurgical data presented are of considerable value to designing and station engineers, but there is still scope for research in the laboratory, foundry, welding shop and on sites, particularly if tidal or pumped-storage schemes utilising sea water become feasible projects.

(To be continued)

A New Plan for the Nile

A new Nile Valley development plan has just been completed by the Sudanese Ministry of Irrigation and Hydro-electric Power in Khartoum. At present, much of the water of the Nile is wasted and many of the riparian countries would benefit by a comprehensive development of the river. The mean annual flow at Aswan is about 84 milliard cu. m., although the discharge varies between approximate limits of 40 and 150 milliard cu. m. according to season and climatic conditions. Besides the large losses due to evaporation, some 30 milliard cu. m. flows into the sea each year because adequate storage is absent.

The plan provides for the annual hydro-electric generation of a million kWh in the Sudan, two million kWh in Uganda, about 500,000 kWh in Egypt at Aswan and a large amount in Ethiopia. A modified, smaller dam is suggested for the Aswan project and the plant also provides for dams on Lakes Albert, Kioja and Victoria, the last of which is already in existence at Owen Falls. Dams would also be built at Lake Tana, on the Blue Nile, and on the Sobat, and a tunnel would connect Lake Tana to the headwaters of the river Balas. A new dam would also be built at Roseires on the Sudan section of the Blue Nile. There are several other structures intended mainly for irrigation and the project also includes dams at Sabaloka, the Fifth Cataract, Merowe and Senina, all of which are between Khartoum and Wadi Halfa on the Egyptian frontier.

Although it is hoped that the World Bank will assist in financing this development, in previous negotiations it has been said that prior agreement between all the parties concerned would be a condition of such a loan; such agreement does not yet exist. If the plan is eventually put into execution, enormous areas will be opened up to development.

High-Discharge Truck Mixers. A coloured leaflet issued by Ransomes & Rapier Limited of Ipswich gives particulars of 3½, 4 and 4½ cu. yard capacity truck-mounted mixers and concrete agitators.

Design of Pipeline Anchor Blocks

This analysis takes into account the moments involved due to the unbalanced radial forces around a bend

By ERIK SOLLID, B.S., M.S., M.A.S.C.E., A.C.I.

LITERATURE on pipeline anchor design fails to emphasise a very important feature of such design, namely that of checking into and designing against the moments involved due to the unbalanced radial forces around the bend of a bent pipe. Fig. 1 shows a pipe bend between two expansion joints to be supported by a properly designed anchor block. TR is the resultant of T_1 and T_2, the axial forces at point of tangency 1 and 2 respectively. The axial forces due to hydrostatic pressure at points 1 and 2 transplant themselves around the bend by unbalanced radial forces that may be found as follows. In Fig. 2 the pressure d_{pr} on the shaded element of the pipe surface is

$$d_{pr} = pr\, d\alpha (R + y)\, d\theta \qquad \ldots(1)$$

$(R + Y)\, d\theta$ being the length of the element perpendicular to the section (see Fig. 1). The component d_{pd} of this force in the direction of the radius R is

$$d_{pd} = d_{pr} \cos \alpha = pr\, d\alpha\, (R+y) \cos \alpha\, d\theta \qquad \ldots(2)$$

Integrating this from $\alpha = 0$ to $\pi/2$, and $\alpha = 0$ to $-\pi/2$, that is, summing up the forces for the outside half of the pipe section gives:

$$P_{d_0} = -2pr\left(R - \frac{r\pi}{4}\right) d\theta \qquad \ldots(3)$$

For the inside half of the pipe section, the same integral is used except that $(R + Y)$ must be replaced by $(R - Y)$. This gives, for the inside half,

$$P_{di} = -2pr\left(R + \frac{r\pi}{4}\right) d\theta \qquad \ldots(4)$$

The unbalanced radial load in the direction of R (Fig. 1) will now be the difference between P_{d_0} and P_{di}, or

$$d_{PR} = p\pi r^2\, d\theta \qquad \ldots(5)$$

The component of d_{pR} in direction of the support T_R would be

$$d_{PD} = d_{pR} \cos \theta = p\pi r^2 \cos \theta\, d\theta \qquad \ldots(6)$$

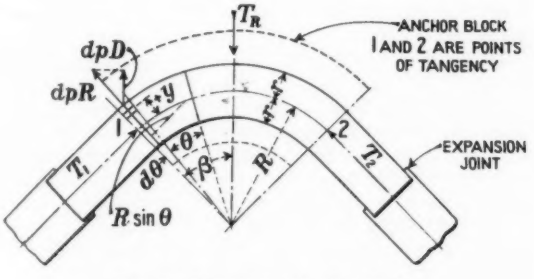

Fig. 1. Diagram of pipe bend

and the total force T_R would be found by integrating equation (6) and multiplying by 2:

$$T_R = 2p\pi r^2 \sin \beta \qquad \ldots(7)$$

It is seen that this is the resultant of the two forces $T_1 = T_2 = p\pi r^2$. For design purposes it is clearer to look at the actual distribution of the resultant bend forces than the resultants themselves since it not only gives the magnitude of the total anchor block force T_R but also shows how the block must be distributed around the bend to avoid moment stresses both in the pipe and the anchor block itself. If in equation (5) $d\theta = 1$ (that is, one radian), we get the unbalanced radial force per ft. of pipe along the bend by dividing by R. Denoted by p_R, the radial force per ft. is

$$P_R = p\frac{\pi r^2}{R} = \frac{T_1}{R} = \frac{T_2}{R} \qquad \ldots(8)$$

This relation holds, no matter what causes the forces T_1 and T_2. Equation (8), therefore, gives a convenient means of computing the equivalent radial forces caused by axial forces such as friction on bearing blocks, or the equivalent axial thrust caused by the centrifugal forces of flowing water around the bend. Thus, if the pipe bend was in a horizontal plane, the weight, $w\sigma$, of the anchor block per ft. at radius R multiplied by the coefficient of friction f, on the foundation material would have to equal p_R if the block and pipe is to be free of moment stresses. Thus

$$w = \frac{T_1 C}{f_R} \qquad \ldots(9)$$

where c = the factor of safety.

The total weight of the block would be W or

$$W = \frac{2T_1 R\beta C}{fR} = \frac{2T_1 \beta C}{f} \qquad \ldots(10)$$

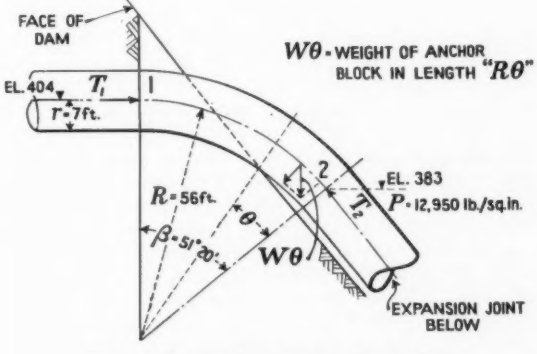

Fig. 2. Penstock emerging from dam

This is $\beta/\sin\beta$ heavier than a block required to produce a friction force equal to TR_1 which for small values of β is negligible, but the important point is that the distribution per ft should be as given by equation (9) if bending stresses are to be avoided. The moment at the centreline of the pipe at any angle θ caused by the unbalanced radial forces may be obtained as follows. The moment θ of d_pR (Fig. 1) is:

$$d_{M\theta} = d_pR \sin\theta = pr^2\pi R \sin\theta\, d\theta \quad ...(11)$$

Integration gives the moment at any angle θ as

$$M_\theta = p\pi r^2 R(1-\cos\theta) = P_R R^2(1-\cos\theta) ...(12)$$

That is M_θ = Unbalanced Radial thrust per ft. $\times R^2(1-\cos\theta)$. As a check it may be observed that this moment is equal to T_1 times its eccentricity at the centreline of the pipe at angle θ, or

$$M_\theta = T_1R(1-\cos\theta) = P_R R^2(1-\cos\theta) \quad ...(13)$$

Since T_1 usually includes other forces than the hydraulic thrust, the moment is best obtained by the first part of equation (13).

The moment caused by the centrifugal force of flowing water may readily be obtained as follows. The radial thrust P_R due to flowing water would be the centrifugal force of the water per ft. of pipe or

$$P_R = \frac{62{\cdot}5\pi r^2}{g} \times \frac{v^2}{R} = 6{\cdot}1\frac{r^2v^2}{R} \quad ...(14)$$

where v = velocity of water in ft. per sec. By equations (8) and (14), it is seen that the equivalent axial thrust of flowing water

$$T_1 = 6{\cdot}1r^2v^2 \quad ...(15)$$

This force may therefore be added to all other axial forces and as a summary we have:

$$W = \frac{\sum T_1 \times C}{fR} \quad ...(16)$$

$$W = \frac{2\beta\sum T_1 \times C}{f} \quad ...(17)$$

$$M_\theta = \sum T_1 \times R(1-\cos\theta) \quad ...(18)$$

To summarise, the various components of T_1 and T_2 are:

(1) For hydrostatic pressure

$$T_1 = p\pi r^2$$

(2) Flowing water

$$T_1 = 6{\cdot}1r^2v^2$$

(3) Sliding friction on bearing blocks, on either side of the anchor block, in each case due to expansion or contraction.

(4) Axial forces due to dead weight of pipe when located on a slope.

(5) Sliding friction of the expansion joints.

(6) Hydrostatic pressure on pipe ends at the expansion joints.

(7) Hydrostatic pressure on reducers that might be present.

If the anchor block is in a vertical plane as shown in Fig. 2, then the radial component of the weight of the block per ft. (pipe and water included) must equal $(\sum T_2 \times C)/R$. The tangential component should not exceed the friction force of the anchor block as seated on the dam. As far as moments are concerned therefore, the effect of the tangential component may be disregarded. This is not correct as far as the weight of water is concerned but allows a margin of safety. In this example, the forces enumerated above are:

(1) $T_2 = 12{,}950 \times 3{\cdot}14 \times 7^2$	=	2,000,000 lb
(2) $T_2 = 6{\cdot}1 \times 7^2 \times 12^2$	=	43,200 lb
(3 to 7) Assumed to be	=	100,000 lb
$\sum T_2$ =		2,143,200 lb
		say: 2,145,000 lb

From Fig. 3 it is seen that the radial component of $W\theta$ is:

$$W_\theta \sin\left(90 - (51^\circ - 20') + \frac{\theta}{2}\right) = \frac{\sum T_2}{R}\frac{\theta}{57{\cdot}3}R$$

or

$$W_\theta \sin\left(38^\circ - 40' + \frac{\theta}{2}\right) = \sum T_2 \frac{\theta}{57{\cdot}3}C$$

where θ is in degrees.

This gives

$$W_\theta = \frac{\sum T_2 \times \theta C}{57{\cdot}3 \sin(38^\circ - 40' + \theta/2)}$$

Checked for $\theta = 5^\circ$; $R\theta = 4{\cdot}9$ ft; $C = 1{\cdot}25$

$$W_{5^\circ} = \frac{2{\cdot}145 \times 5 \times 1{\cdot}25}{57{\cdot}3 \times \sin 41^\circ - 10'} = 356{,}000 \text{ lb}$$

Weight of water and pipe

$$= 3{\cdot}14 \times 7{\cdot}42^2 \times 62{\cdot}5 \times 4{\cdot}9 = 52{,}800 \text{ lb}$$

This leaves 356,000 − 52,800 = 303,200 lb which is equivalent to 2,000 cu. ft of concrete

Nuclear Batteries

It seems very likely that radioactive waste products, which nowadays are troublesome and often difficult to dispose of, will eventually find an important industrial use as a portable source of electrical energy. Batteries could be produced in a number of ways; beta particles ionise gases and these ions could be used to stimulate current flow from dissimilar metals. Another type could collect high-speed electrons from the radioactive waste by means of an adjacent conductor. In another battery the radiation could be used to energise the operation of a semi-conducor diode, a unit similar to a transistor.

Already nuclear batteries have applications in military research; these are used on a very small scale and would probably not be claimed to be economic, but when waste-product-recovery systems in reactor plant are improved these should give rise to larger and cheaper supplies of isotopes and make commercial batteries an economic proposition.

Energy from a nuclear battery would be available for very long periods of time, and this time would be predictable with considerable accuracy. An important property would be that, since the decay of radioactive isotopes is not affected by temperature change or short circuiting, the battery would have complete stability.

It is only the beta particles which would be of real use for this application; alpha particles would be absorbed in the electrical converter and in the isotope itself and gamma rays would be most undesirable because of the shielding required to prevent external radiation. Large-capacity batteries would therefore suffer from the need for cumbersome shielding.

For providing an energy source in places where normal power supplies are inaccessible, nuclear batteries would have the valuable advantages of long shelf life and immunity from environmental effects.

Ground Vibrations in Blasting

This article deals with the measurement and character of ground vibrations caused by blasting and makes recommendations by which the intensity of the vibrations can be reduced and damage to structures or property avoided

By *U. LANGEFORS, H. WESTERBERG and B. KIHLSTROM

PART THREE

Planning Blasting Operations

If ground-vibration problems are likely to arise, an estimate of their effects should be considered in the planning work. As a basis the risk of damage as a function of the size of the charge and distance between the charge and structures has to be determined. Such a relation is given in Fig. 18, which represents a summary of our experimental experience. The values apply to blasting in solid bedrock in which the houses have their foundations. In making out this diagram we have only included unfavourable values. If a single case of damage has been discovered in a series of 50 observations for a certain distance, and with a given charge, it has been included. The diagram thus covers the most unfavourable cases which we have found, and represents a great number in the range 2–30 m. from the blasting site. In principle, the table does not indicate that in blasting, e.g. according to line 2, cracking is certain to be avoided, but that in the given conditions it is improbable. Nor can the conclusion be drawn that damage will inevitably be incurred in the area between lines 3 and 4; the diagram merely indicates that risk of cracking can be expected in this area if the ground conditions are not known, which is generally the case. The values along line 3 are also given in Table III.

TABLE III. LARGEST CO-OPERATING CHARGE IF LINE 3 IN FIG. 18 IS NOT TO BE EXCEEDED.

Distance m.	Charge Q kg.
0·5	0·02
0·75	0·04
1·0	0·06
1·25	0·09
1·5	0·12
2·0	0·16
2·5	0·25
3·0	0·3
3·5	0·4
4·0	0·5
6·0	0·9
8·0	1·3
10·0	2.0
15·0	3·8
20·0	6·5
25·0	8·0
30·0	11·0

* Nitroglycerin A.B. and Swedish Detonation Research Foundation, Stockholm.

The course of the calculation is as follows: Taking into consideration the nature of the buildings likely to be affected, the values given in Fig. 18 should be applied according to the risk level corresponding to one of the lines 1–3, 3. This level is first chosen so that the probability of damage is estimated to be practically negligible. By making use of the possibilities which we have already enumerated, the problem can often be solved without reducing the size of the individual charges in the holes, or the total quantity of charge used in the round. In other cases the planning must be changed so that the charges and size of round are

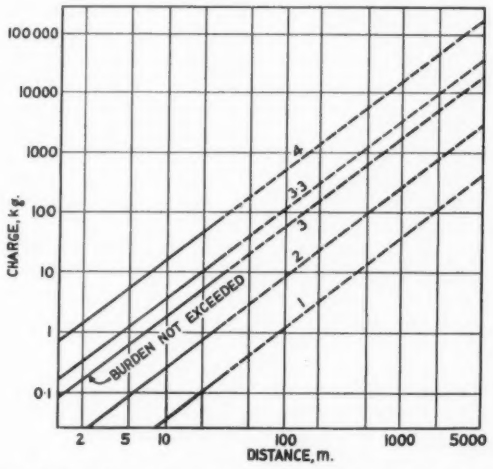

Fig. 18. Condensation of experience up to the present of connection between amount of charge, distance and damaging effect on normal house building. Blasting with free breakage. (4) Pronounced damaging effect. Fall of stone in galleries and tunnels; (3·3) Cracking in repeated blasting. (3) Insignificant cracking in repeated blasting. (2) Fall of plaster. No cracking has hitherto been discovered. (1) Fall of very loose plaster. The unbroken lines 1–4 have been made out for distances of 2–30 m. when blasting in normal Swedish bedrock. Marked fixation can give more damaging results (e.g. in seismic prospecting). The diagram is based on a considerable amount of material which has been contributed by the Street Department of the City of Stockholm, in addition to Nitroglycerin AB's own measurements

reduced. If this is not economical, or undesirable in some other way, then blasting with a higher risk level must be accepted and the cost of compensation considered.

If the charge allowed (Fig. 18) is indicated by Q, the charge quantity in the same interval by Q_i, the reduced charge by Q_{red}, then

$$Q_{red} = r\ Q_i \qquad \ldots (20)$$

will apply, the first condition being that this charge quantity will be smaller than Q.

$$Q_{red} \leq Q \qquad \ldots (21)$$

This condition is also sufficient if the interval time (the mean value) exceeds $3\ T$.

At slow natural vibrations in the ground when $\tau < 3\ T$, co-operation may take place between the different groups, each one of which is represented by Q_{red}. This co-operation does not occur, however, between the interval numbers which have a time distance of $3\ T$, or more. If $\tau = T$, for example, then intervals 1, 2 and 3 will co-operate, but not 1 and 4 or higher numbers, nor will 2 and 5, etc. Here the condition will be

$$3\ Q_{red} \leq Q.$$

If the interval times are $\tau < T$, then generally $\Delta\tau < T/2$ and the reduction factor can be calculated $r = 1$. The total charge in an interval, Q_i, co-operates, but a reduction can be effected between the different units of Q_i by a regular interference in keeping with the condition (19) so that the effect does not exceed that from an individual interval.

Practical Directions

To make clear how the calculations are made in practice some examples will be discussed of blasts which have been carried out in recent years. These examples have been chosen as typical cases. Unless otherwise indicated a reduction factor r according to Table II is used, with $f = 100$ *p/s*, and with line 3 in Fig. 18 indicating the largest co-operating charge (Q) allowed, this being given for different distances in Table III.

Example 1. Blasting of 60,000 cu. m. of foundations close to flats. The foundation is to be blasted to a depth of 20 m. The bench height can either be 5 m. with 4 shelves, or 6–7 m. with 3 shelves. If the first alternative is chosen the depth of hole will be about 5·5 m., and the boring diameter at the bottom 28 mm. This makes a maximum burden of 1·3 m. at the bottom. Allowing for normal inaccuracies in boring (5 cm. per m.) the burden must be reduced to $V = 1{\cdot}0$ m. The corresponding distance of hole will be $E = 1{\cdot}25$ m. A borehole will then suffice for the blasting of an area $VE = 1{\cdot}25$ sq. m. This applies even if a greater burden is chosen, compensated by a shorter hole so that the area per hole remains constant, e.g. $V = E = \sqrt{1{\cdot}25}$ m. This makes 6·25 cu. m. per hole. The desired fragmentation determines the final amount of charge per cu. m. (the specific charge) to be $Q = 0{\cdot}30$–$0{\cdot}35$ kg. per cu. m. The total size of charge per hole will be $Q_i = 2$ kg. According to Table III this charge can be used for a distance of ≥ 10 m. from neighbouring houses. Up to this distance the placing of holes need not be changed with regard to the ground vibrations, provided that the size of charge which co-operates does not exceed 2 kg. In the present case the interval time is $T = 30$ millisec. and the natural vibration time of the ground wave

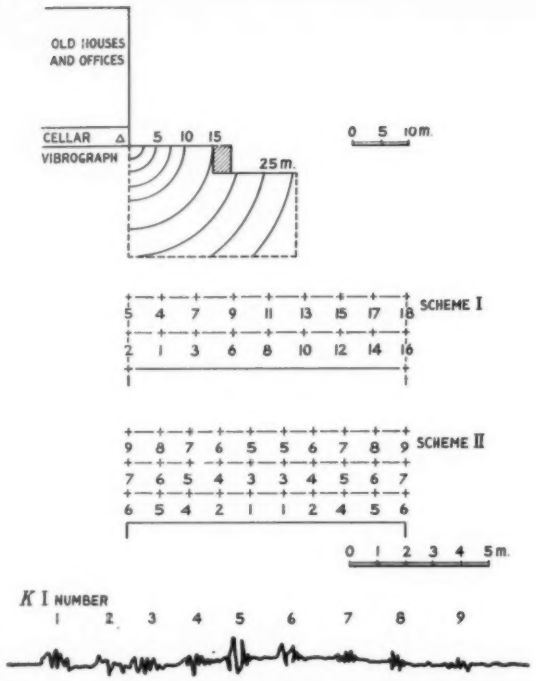

Fig. 19. Blasting of foundation close to dwelling houses. Upper picture is a profile; the two lower diagrams are drilling and igniting patterns for rounds. Size of rounds ca. 150 cu. m. Foundation 60,000 cu. m.

$T \leq 10$ millisec., i.e. the condition $\tau \geq 2{\cdot}5\ T$ has been fulfilled. The charges in different intervals do not then co-operate and 2 kg. can be blasted in every interval. The round can amount to 32 kg. with intervals with Nos. 0–15. The blasting can be done according to Alt. I in Fig. 20.

A reduction effect can also be counted on within the same interval with short-delay caps, as will be seen from Table II. For interval No. 0 $\Delta\tau = 0$ applies, for Nos. 1, 2 and 3 $\Delta\tau = \pm 5$ millisec. and for higher numbers $\Delta\tau = \pm 10$ millisec. or greater. The reduction factor then is $r = 1$, 1/2 or 1/3 respectively, i.e. the size of the charge in every interval will be as indicated in Table IV.

TABLE IV. AMOUNT OF THE CHARGE FOR DIFFERENT INTERVALS

Interval No.	...	...	...	0,	1,	1,	1,	4,	5	...	15				
Total charge quantity kg.			...	2,	4,	4,	4.	6,	6	...	6				

The total charge of the round can then amount to 84 kg. This is an enormous increase in the charge quantity, but with the ignition pattern mentioned the only risk incurred is that two charges within the same interval may just happen to co-operate by chance in a vibration effect corresponding to 4 kg. Utilising the reduction factor r implies that a relatively small probability is counted on for co-operation taking place, not that it is excluded. If we insist that the charge quantity according to Table III must in no circumstances be exceeded, the total charge quantity is limited to 32 kg. with only one charge in every interval.

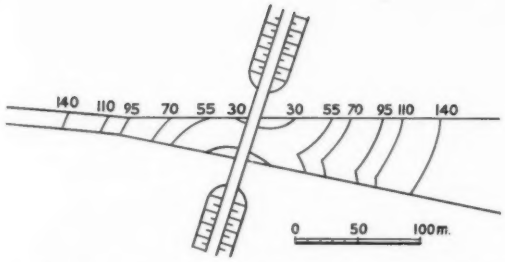

Fig. 20. Blasting of a canal beneath a bridge. Bench height 11 mm. Figures give distance in m. from nearest bridge foundation

In Fig. 20 a vibrogram is shown of a blast according to Alt. II with 60 kg., which has been correctly distributed for interval Nos. 1, 2 and 3, and also 7, 8 and 9, having regard to the reduction factor $r=1/2$ or 1/3. For the other interval Nos. 4, 5 and 6 the total charge quantity/interval has been 4·2, 6·2 and 6·2, and the reduced charge quantities 2·7, 4 and 4 kg., i.e. double the desired charge quantity. The vibrogram shows also that the greatest vibration effect was obtained in these intervals 4, 5 and 6. This could easily have been avoided if the number of intervals had been increased. The vibrogram also clearly shows that a further increase in the charge quantity to 84 kg. by utilising, according to Table IV, all intervals 0–15, would not in any way augment the vibration effect.

Some further facts may be pointed out in conjunction with the vibrogram. The two holes with No. 1 are more tightly wedged than the two which follow with No. 2. This is directly shown on the vibrogram by stronger deflections for No. 1 than for No. 2. If we compare Nos. 1 and 4 it will be seen that No. 4 has given a greater deflection than No. 1, but the difference is insignificant. It seems as if Q_{red} for No. 4 has been 35 per cent. larger than for No. 1 (2·7 kg. compared with 2 kg.) has been counteracted by No. 4 having had a freer deflection. Another fact which is worth pointing out is that the vibration effect diminishes the higher the interval numbers; compare, e.g., Nos. 4 and 7. The reason for this, of course, is the increasing scattering in ignition time. As will be seen from Table II this diminishes the reduction factor.

Example 2. Blasting of a canal below a road bridge (Fig. 20). The bridge was not built when the work was being planned, but it was considered important for various reasons to complete the bridge before the blasting was started. The bench height enabled large-diameter holes to be drilled. Those of immediate interest had diameters =100, 88 and 51 mm. Fully loaded these holes required 108, 70 and 25 kg. of explosive per hole.

Taking these values as a starting point, a plan can be made showing the connection between the distances from the bridge abutments and hole diameters. Taking values according to line 3 in Fig. 18 as the limitation for the charge in each individual hole, 140 m., 110 m. and 55 m. are then obtained as the minimum distances with fully charged holes. This means that blasting at distances greater than 140 m. can be done by taking into consideration the ground vibrations only as far as a suitable division of intervals is concerned. For shorter distances, down to 95 m., it is also possible to maintain the diameter of hole at 100 mm. if the charge in a hole is divided into two parts of approximately 60 kg. each. The two-part charges are then ignited at different intervals. If so, it assumes that to separate the charges dry sand to a length of 2 m. is inserted between them.

Dividing a charge into more than two units in one 100 mm. hole is not advisable in view of the relationship between the burden (about 4 m.) and the length of the charges.

The diameter of the holes must be reduced for a distance under 95 m. Even with 80 mm. holes it is necessary to divide up charges into 2 or 3 units, which can be ignited independently of one another. This division of the charges can be used at distances down to 55 m. At lesser distances diameter of holes must be still further reduced. Table V gives a compilation of the possibilities which are offered. The rock affected by the restriction due to ground vibrations will be about 100,000 cu. m.

TABLE V. DISTRIBUTION OF CHARGES ACCORDING TO DATA IN EX. 2.

Distance from bridge abutment m.	Diameter of holes mm.	Kg./hole	Intervals/hole	Kg./Interval
140	100	108	1	108
140–110	88	70	1	70
110–95	100	108	2	60
95–70	88	70	2	35
70–55	88	70	3	25
70–55	51	25	1	25
55–30	51	25	3	10

As has been mentioned, however, the portion of this rock which lies between a distance of 140–95 m. can be blasted without changing the diameter of hole, if the charge in the hole is divided in two units. The increase in cost for this procedure will in all probability be insignificant. At distances of less than 95 m. the measures for reducing ground vibrations must appreciably increase the blasting costs. With 30–40,000 cu. m. of solid rock involved the extra cost of the blasting, even with a moderate increase in percentage cost, may be considerable. When the extra cost has been calculated it can be decided whether the blasting shall be carried out as originally intended or whether the following alternatives should be adopted:—

I. That the blasting be carried out in accordance with a line lying above 3 in Fig. 18, so that all distance values are halved for the same charge quantity. This will reduce the extra cost by more than half, but the risk of damage to the bridge will of course be increased. If this risk implies cracks which can be tolerated, or repaired at a moderate cost, this course may be chosen. The final decision depends on the extent to which the bridge must not be exposed to risk. The great difference which is inherent between a house and a solid concrete structure should be emphasised here, and it should also be pointed out that Fig. 18 refers to house property.

II. Unless the advantages of building the bridge before the blasting has been carried are considered to outweigh the extra cost of the precautions needed, its erection should be postponed until the blasting has

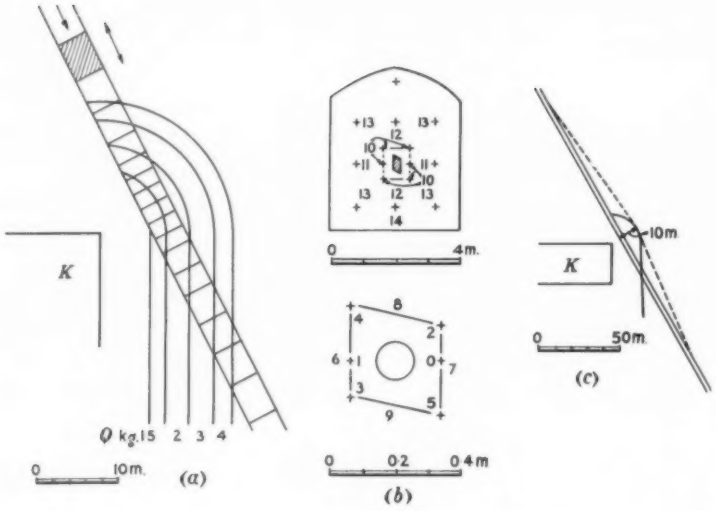

Fig. 21. Blasting of 18 sq. m. tunnel close to a power station (K). (a) Intended direction of the tunnel close to K. The length of the round, 4·8 m., has to be successively reduced to 2 m. (b) Drilling diagram and igniting pattern for the central part of the round. Parallel arrangement of holes round one large hole with a diameter of 110 mm. The figures indicate the sequence of short-delay detonators. (c) If the distance between K and the tunnel is increased by 10 m., the tunnel is extended by 1 m. All rounds can then be made with full advance

progressed 140 m. beyond from the site. The latter alternative was adopted in a practical instance.

Example 3. Blasting of a tunnel close to a power station. The tunnel area is 18 sq. m. At the spot where the tunnel is nearest to the power station the crown lies 6 m. below the lowest part of the concrete foundations of the power station. The length of the round is 4·8 m. and the blasting is directed towards a central, uncharged hole having a diameter of 110 mm.

Fig. 21 shows the distances (8, 10, 13 and 16 m.) from the structure. The corresponding maximum charge is 1·5, 2, 3 and 4 kg. When the distance lines are inserted care must be taken to see that they are obtained by direct measurement on the left part of Fig. 21. The difference in level is 6 m. and the total distance will therefore be $R=\sqrt{d^2+6^2}$. The connection between advance and charge per hole is determined by the depth of hole being approximately equal to the advance, and the charge in the drill hole being $l=1{\cdot}0$ kg. per m. The end half metre of the stope holes is left uncharged. Hence it follows that the advance will be $l=Q+0{\cdot}5$ m., on the assumption that, as in previous examples, an ignition pattern is used which makes it unnecessary to count on the co-operation of two or more holes.

This condition is fulfilled by the ignition pattern shown at the top of Fig. 21*b*. For the central part, with the ten first intervals, the drilling and ignition pattern has been drawn on a larger scale. With the given conditions the length of the rounds must be reduced in stages from 4·8 to 2·0 m., and then again increased to 4·8 m. In this manner a stretch of 43 m. of the tunnel length will be blasted with a reduced advance, the number of rounds being increased from 9 to 14.

As an alternative the possibility of increasing the distance between the tunnel to the power station may be considered. If the tunnel is moved 10 m. from the nearest point of the power station the length will be increased as shown in Fig. 21*c*. The distance from the power station to two points where the location of the tunnel was determined for other reasons was about 100 m. in either direction. This will only add 1 m. to the total length of the tunnel. It is clear, therefore, that the extra cost of the cautious blasting, with 14 rounds instead of 9, will be considerably higher than for this insignificant addition to the length.

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(Continued on page 433)

Fig. 1. Furnas dam site, looking downstream

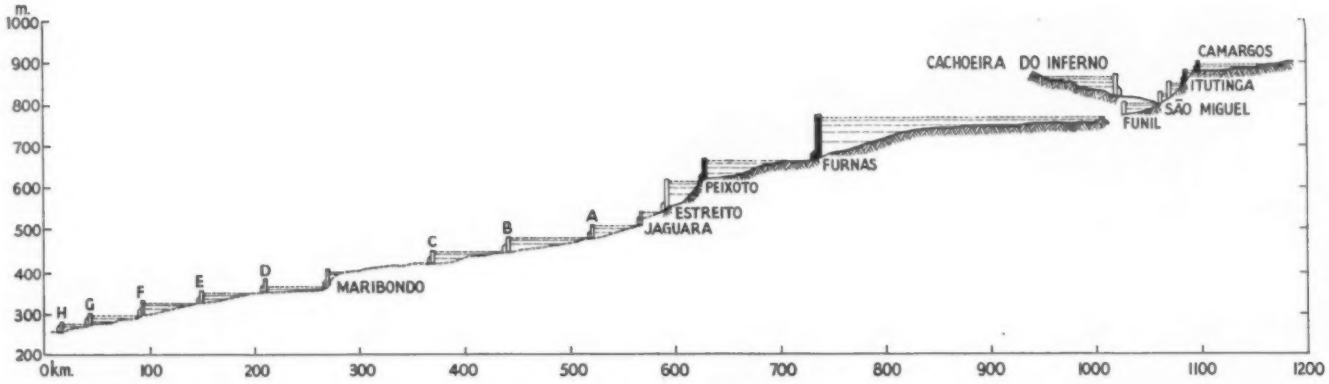
The Furnas Hydro-Electric Development

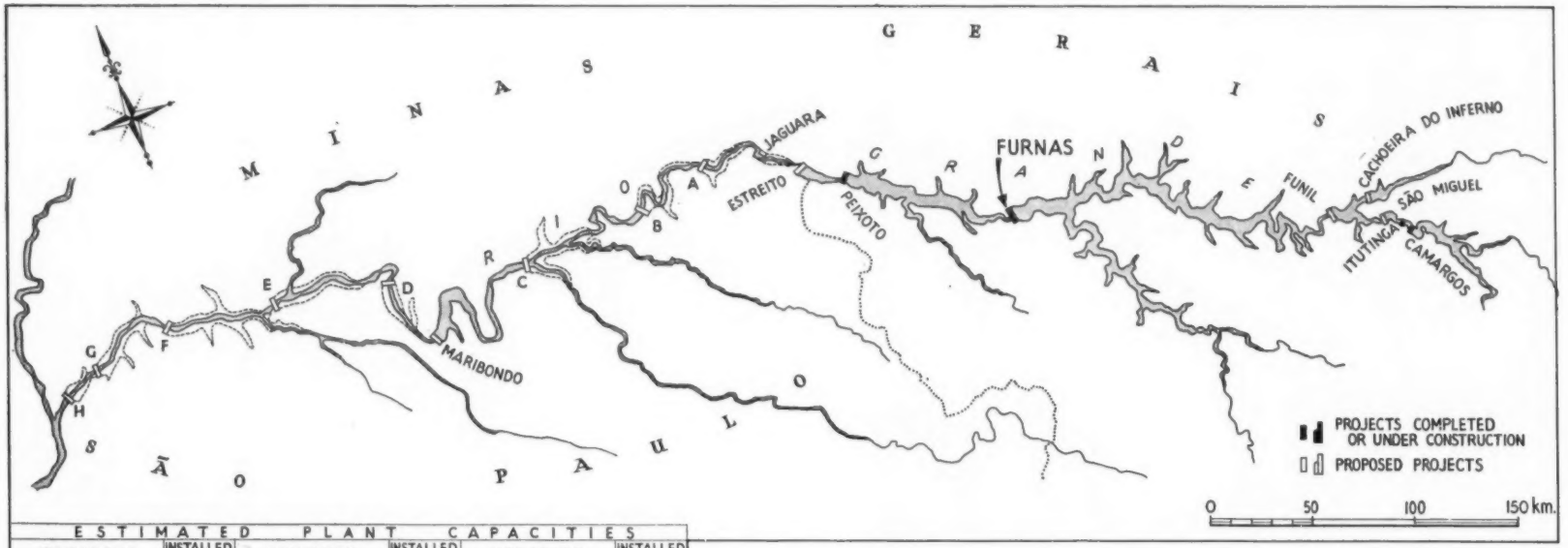
An outline is given of this 1,100 MW project on which work has just commenced. It will be the largest development in Brazil and probably the largest single station in the Southern Hemisphere

By Dr. JOHN R. COTRIM,
Director President, Central Elétrica de Furnas S.A.

THE Furnas hydro-electric development on the Rio Grande in Minas Gerais—a 1,100 MW project comprising a fill-type dam and storage reservoir for pluriennal regulation of streamflow—will supply power in bulk to the major electric utilities operating in central and southern Brazil. This is the most progressive area in the country, comprising 7% of the area and 37% of the national population, producing 69% of the agricultural and 78% of the country's industrial output. The area contains the Brazilian capital, Rio de Janeiro, with a population of 2,940 thousand; the city of São Paulo (pop. 3,150 thousand), Latin America's largest industrial centre, and Belo Horizonte, state capital of Minas Gerais, a modern and progressive city of 500 thousand people, close to the country's richest mineral deposits and to the greatest national concentration of mining and metallurgical industries. The high rate of industrialisation in this area calls for a commensurate power-development programme in order to prevent a very acute power shortage in the near future.

The Furnas project is a key factor in the Brazilian electrification scheme, due (a), to the magnitude of its proposed installed capacity (1,100 MW); (b), to the possibility of interconnecting the area's isolated power systems into an integrated power pool by means of transmission links radiating from its central position with respect to the major industrial areas of São Paulo, Rio de Janeiro and Belo Horizonte; and (c), to its firming ability on downstream projects on the Rio Grande. The total Rio Grande potential capacity, of which the regulating effect of the Furnas reservoir is a key factor, is estimated at 7,000 MW, which is more than twice the present installed capacity in the





ESTIMATED PLANT CAPACITIES

PROJECTS	INSTALLED MW	PROJECTS	INSTALLED MW	PROJECTS	INSTALLED MW
CAMARGOS	35	PEIXOTO	440	MARIBONDO	660
ITUTINGA	50	ESTREITO	900	D	310
SÃO MIGUEL	80	JAGUARA	450	E	400
CACHOEIRA DO INFERNO	35	A	380	F	550
FUNIL	90	B	380	G	330
FURNAS	1100	C	480	H	330
				TOTAL	7000

Fig. 2. Map and profile diagram of the development scheme for the Rio Grande

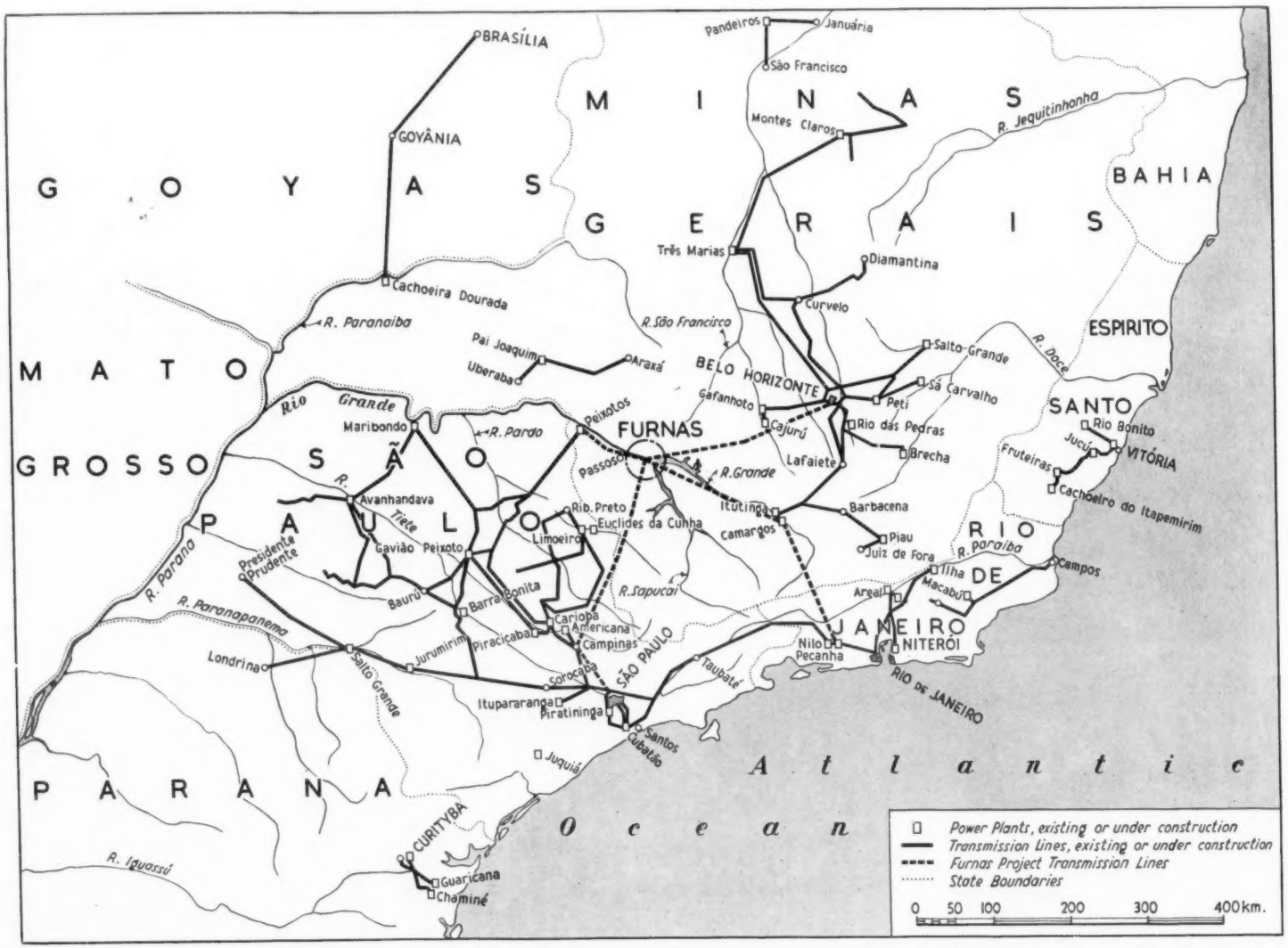


Fig. 3. Main electrical transmission network, showing the Furnas zone of influence

whole of Brazil. The Rio Grande, which originates in the state of Minas Gerais mountain ranges near the coast, at about the latitude of Rio de Janeiro, is one of the main formers of the Paraná River, which in turn becomes the River Plate after receiving the waters of the River Uruguay.

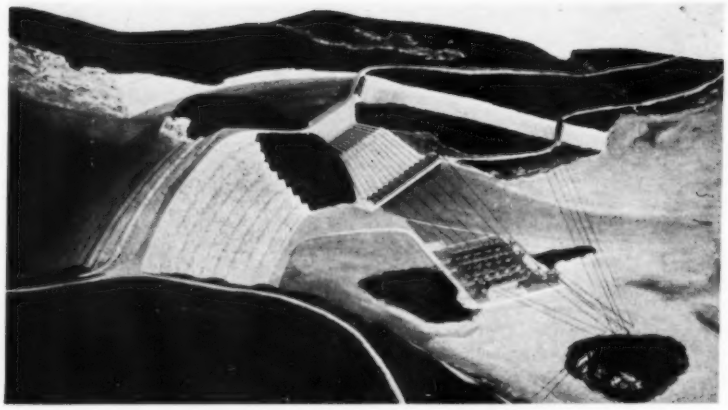


Fig. 4. Model of Furnas dam and power house

Details of the Project

Basically, the project consists of a fill-type dam and storage reservoir, side-channel spillway, intake structure, penstocks, power house and switchyard. The dam, one of the largest of its kind in the world, will be a multi-zoned compacted clay and rockfill structure 120 m. high, with a crest length of 550 m., which will require approximately 10 million cu. m. (13 million cu. yards) of fill material. Water diversion during construction will be effected through two diversion tunnels 700 m. long, each with an equivalent diameter of 15 m.

Problems connected with the reservoir will constitute one of the project's major items. The reservoir will be the largest of its kind in the country, covering an area of 1,600 sq. km. (620 sq. miles), the equivalent of the Brazilian Federal District. The flooding of the areas involved will call for the acquisition of 1,800 sq. km. (695 sq. miles) of land and the relocation or rebuilding of several towns, many bridges and over 210 km. (136 miles) of rail tracks and highways. Political, social and economic problems will have to be solved, and local improvement programmes will have to be implemented, before work on the reservoir may be said to have successfully concluded. Once completed, however, its location in a well-favoured area at an elevation of over 2,500 ft., with a mild and agreeable climate, within easy reach (one-hour distance by air) of the cities of Rio, São Paulo and Belo Horizonte, will certainly convert the area into an attractive zone for tourists.

The reservoir is designed for normal operation within a 16 m. drawdown from the maximum pool elevation of 766 m. The corresponding useful storage will be 14 billion cu. m., or 11·3 million acre-ft. At a short distance upstream from the Furnas site, the reservoir will branch out for 240 km. (149 miles) along the Rio Grande, and 170 km., or 106 miles up the Sapucai, its principal affluent in the area. The catchment basin feeding the reservoir will have an area of 52,000 sq. km. (20,000 sq. miles), which is more than half the area of Portugal.

The Furnas reservoir with maximum water surface elevation will back water into the Pium-i river valley. At the upper end of this valley there is a low saddle (elevation 747 m.) through which water could spill into the São Francisco river, another main stream of the Brazilian hydrographic system which flows north into the Atlantic Ocean close to the Brazilian north-eastern bulge. To prevent this, it is planned to block the saddle with an earth embankment about 35 m. high and 460 m. long.

The spillway associated with the main dam will pass a flood of 13,000 cu. m. per sec. at elevation 769 m., and 10,500 cu. m. per sec. at elevation 768 m. This should be ample in comparison with the maximum recorded (1929) flood of 5,261 cu. m. per sec. The regulated discharge will be 877 cu. m. per sec. which, for an average head of 91 m., will yield 650 MW net output of firm power during an average year.

The installed capacity, based on a plant factor of the order of 60%, will be 1,100 MW. There will be eight generating units of 190,000 h.p. each. The transmission system, at 400 kV, will interconnect Furnas with the major utilities operating in Minas Gerais and São Paulo.

Construction Schedule

Construction is planned to be completed in two stages. During the first stage all civil and hydraulic works will be completed, and four of the generating units will be installed. Work on the project proper commenced in the middle of 1958, with cofferdamming, tunnel excavation, main dam excavation and tailrace channel excavation. It is expected that the main dam, forebay, intake, spillway, power-house substructure, tailrace, accessory reservoir works and purchase of land rights, road and town relocation, will be completed early in 1962, and the first four generating units, with penstocks, control equipment, step-up transformers and transmission circuits for interconnection with the São Paulo and CEMIG power systems, will be installed and operative from March to December 1962. The second stage will consist of the progressive installation of the remaining power generating units, from January 1964 to July 1965.

The total cost of the development is estimated at 200 million dollars.

Construction operations will be carried out by a joint venture partnership comprising the firm of George Wimpey & Co. Ltd., of England, and Companhia Construtora Nacional S.A. of Brazil, who submitted the winning tender in competitive bidding with 20 other widely known contractors from six different countries.

Company and Financial Arrangements

The project will be carried out under the responsibility of Central Elétrica de Furnas S.A.—(FURNAS)—a company created for the express purpose of constructing and operating the Furnas hydro-electric

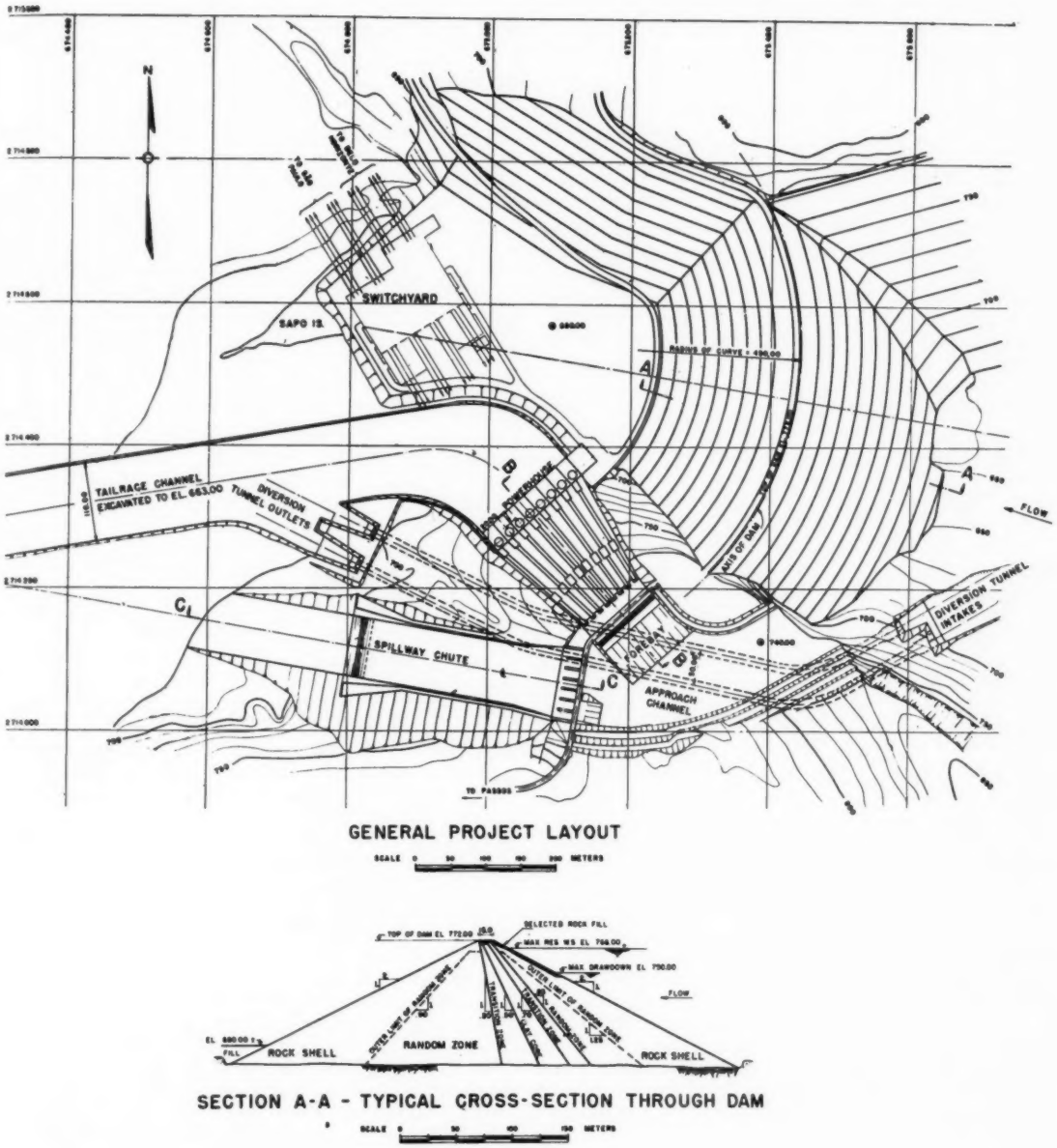


Fig. 5. Layout of Furnas project and cross section through dam

power plant. FURNAS is a joint corporation of government agencies and private utilities operating in the States of São Paulo and Minas Gerais. Common stock will be held by the Federal Government through its participating agent, the National Bank for Economic Development, and by the Minas Gerais and São Paulo State Government agencies for electric power development, CEMIG and DAEESP respectively.

Preferred stock will be taken mostly by private corporations; the greater part will be held by São Paulo Light S.A.—Serviços de Eletricidade, the largest electric utility in Brazil, of the Brazilian Traction, Light & Power group. A small amount will be held by Companhia Paulista de Fôrça e Luz, a subsidiary of American & Foreign Power. This arrangement makes it possible for FURNAS to draw upon the combined experience, know-how, and technical and administrative talent of the participating entities.

Nuclear Power Conference

Many references were made at the recent Geneva Conference on the Peaceful Uses of Atomic Energy to the role of water power in the electricity supply pattern of the future

THE Second United Nations International Conference on the Peaceful Uses of Atomic Energy, held in Geneva from September 1 to 13, proved beyond doubt that nuclear power will not in any way displace water power for at least the next 25 years, and after that it may well prove the perfect partner for the enormous hydro-electric projects which will by then have been completed, together with those now existing, which will continue faithfully to serve the consumers of electricity in all parts of the world.

The papers, although obviously devoted to nuclear matters, gave interesting glimpses into the future energy needs of various countries, and the methods which they propose to adopt to meet them.

The first technical session of the conference was devoted to surveys from various sources of the need for nuclear energy in the major industrialised countries.

Britain has the largest nuclear power programme, and will have the world's first major "partnership" scheme for linking nuclear power with pumped storage. A paper by Messrs. J. C. Duckworth of the Central Electricity Generating Board and E. Hywel Jones of the South of Scotland Electricity Board discussed in detail the scheme to improve the load factor on the 400/500 MW nuclear station to be built at Trawsfynydd in North Wales by means of the 300 MW pumped-storage scheme at Ffestiniog; and the authors touched also on the proposals for a 300 MW scheme in the Galloway area of the South of Scotland Electricity Board and the Loch Awe scheme for the North of Scotland Hydro-Electric Board, both of which might work in conjunction with nuclear plants.

The authors, referring more particularly to the Trawsfynydd-Ffestiniog linkage, said that the shape of the 24 hour load curve would determine the maximum pumping period, and during mid-week this could be assumed to be 7½ hours each night. They gave the efficiencies of the component parts of the scheme as follows:—

Motors	97·5%
Pumps	85·0%
Aqueducts (up and down)	96·0%
Water turbines	90·5%
Generators	97·5%

and so they estimated that the overall efficiency for the full cycle would be about 70%. While actually generating the sets might not always be running at the most efficient load, so the overall average efficiency would be 66–69%. Full-load generation would be possible for a little over 5 hours or perhaps 5½ hours by extra pumping at week-ends. It was shown from these figures that the fuel costs of pumped-storage units would be increased in the ratio of 100/66 or somewhere in the region of 50% compared with the fuel costs of a direct supply from the generating station.

From this, the authors drew the conclusion that the operating costs of a combined steam generation and pumped-storage scheme would therefore be no better than those of "medium-merit" steam plant working on its own, and as the price of coal increased these costs would also increase. Used in conjunction with nuclear plant, however, with fuel replacement costs of about 0·13 to 0·19 pence per unit, the pumped-storage plant could return units to the system at an average fuel cost of 0·2 to 0·3 pence per unit, at times when they would otherwise be provided by steam plant with higher fuel costs. This clearly showed the advantages of linking nuclear plant with pumped-storage schemes.

In concluding their paper the authors said that "the case for the installation of a considerable amount of nuclear plant in Britain in the next decade has been demonstrated, *together with associated pumped-storage schemes.*"

Two other British authors touched on the economics of combined nuclear and pumped-storage projects. Mr. W. Szwander, of the Belfast Corporation Electricity Department, headed the main section on his paper "The *necessity* of supplementing nuclear generation with pumped storage." In his conclusions he showed that while the economics of introducing nuclear generation will always be the chief reason for installing pumped storage (especially in smaller power systems), the fact of operating a pumped-storage scheme in a system brings a number of incidental advantages, benefiting as much the nuclear and the conventional stations as the system operation in general.

Mr. Szwander pointed out that with pumped storage, nuclear stations, even in comparatively small power stations, can operate under conditions which achieve the highest nuclear and thermal efficiency. "While it is appreciated that a nuclear station can be designed to be capable of following the required loading variations, there can be no doubt about the fact that the elimination of the need or the frequency of such variations must be beneficial to the nuclear plant both technically and economically, and may even contribute to the reduction of its first cost." With the responsibility for standby duties taken over by pumped storage, the author felt that all types of conventional station would experience considerable simplification of operation and savings, through elimination of the otherwise indispensable maintenance of parts of the plant in a state of hot standby.

Messrs. Geoffrey F. Kennedy and S. J. Cowherd, of Kennedy and Donkin, consulting engineers, of London, in their paper on the economic operation of nuclear reactors in an electric supply system, devoted much of their paper to the estimation of costs of electricity from various types of nuclear plant at different load factors, and showed that with hydro plant with

either small storage or run-of-river conditions the improvement in the overall costs was very considerable. They described various types of reactor, and said that all of them would operate most satisfactorily on base load. Dealing with the general question of installing nuclear plant on any power system, they stressed particularly the need for hydro-electric plant to improve load factor and to supply peak demands. In their final conclusion they said that the use of energy storage, where available, may well be the deciding factor in the choice of power plant.

Before leaving those aspects of the British contribution to the 1958 Geneva Conference which bear specially on pumped storage, it is perhaps as well to see why it is that Britain, with four large nuclear stations at present under construction, has by far the world's largest atomic power programme in being. In the absence of water power and the steadily rising cost of coal (together with the use of this irreplaceable fossil fuel), an alternative source of energy had to be found. The possession of the largest integrated transmission system in the world meant that load could be transferred to and from the nuclear plants with maximum flexibility, enabling them, on the one hand, to be sited at suitable places, and on the other hand to enable them to be given the necessary base load so that they can operate efficiently.

Turning now to the U.S.A., the very large programme of nuclear power experimentation in the United States is not designed, as was frankly admitted by the authors of the American papers, to provide a significant proportion of the country's energy-producing plant in the near future. The world rate of increase in electrical demand of 7% applied also to America, and with the already great demand it meant that vast quantities of new energy-generating equipment would be needed every year. Nevertheless, the present energy requirements are "being met at moderate costs from substantial United States resources of coal, oil, natural gas and falling water, and from supplementary oil imports." However, it was shown that the usable fuel reserves within the United States itself might well be exhausted in about 50 years, and by then the cost of extracting the coal might well rise to double its present figure.

While it was thought that nuclear power could be made to be competitive with conventional methods of power generation in the United Kingdom by about 1962 or 1963, the American papers showed that it would be probably five years after that date before the same situation could be envisaged in the U.S.A. The American papers also stressed the need for high load factors and for the joining of water-power resources to the nuclear-energy plants of the future.

The third great nuclear country, the U.S.S.R., has ample resources of organic fuel and water power. Their principal paper at Geneva stated that the total actual reserves of coal possibly amounted to 7,400,000 million tons of coal and "as to water power resources, considering only promising reserves of relatively large water catchment areas, these may be estimated at 1,200,000 million kWh per annum, equivalent to 137 million kW of average annual capacity." In addition there were natural gas and oil reserves of enormous potential capacity.

Thus, the need to develop nuclear power in the U.S.S.R. was in no way urgent, although it might be more economic, the Russian engineers said, for some districts of the country where considerable parts of Soviet heavy industry were concentrated.

In France, the viewpoint on nuclear energy was that it gave a greater facility in regard to the choice of sites for hydro-electric development. The French papers stated that up to three or four times the present hydro-electric production could be envisaged; but on a long-term basis it was foreseen that the end of hydro-electric equipment is in sight. At the moment, hydro-electric power accounts for about half of French energy needs but "the limitations imposed by nature upon the possibility of using water power at a cost approaching present prices are bound to form a stumbling block for this policy in 15 or 20 years. True, this period may possibly be extended by a few years by resorting to the use of ocean tides, which in France present conditions exceptionally favourable to the harnessing of their power." The French nuclear power programme is under way, and envisages experimental reactors to determine the best type of construction (although the French reactors up to the present follow the British model); and after it has been ascertained that nuclear power in France is competitive with power from other sources, the establishment of one reactor every 18 months was proposed.

In Canada, the basic consideration in regard to the development of a nuclear power programme in a country with enormous hydro-electric resources still untapped was the question as to whether nuclear power could be economic in comparison with a rate per kilowatt as cheap as, if not cheaper than, any existing elsewhere in the world. As some considerable proportion of Canadian power comes from coal, it was stated that to meet competition nuclear power would have to be generated at less than 6 mills per unit, with coal costing $9 per ton. The Canadian scientists thought that by using the heavy-water-moderated type of reactor it was possible that this economic target could be met; but once again, it was obvious that there was no severe pressure on Canadian power engineers to develop a nuclear programme at the earliest possible moment, as in the United Kingdom.

In another hydro-electric country, Italy, the "imminent shortage" of conventional power was made clear by the papers. There is a considerable nuclear programme in Italy involving the construction of over 900 MW of nuclear plant and two contracts have already been placed, one in Britain and one in America. It was, of course, understood that the remaining hydro-electric resources would be developed, and would operate in partnership with the future nuclear plants.

In Sweden, another predominantly hydro-electric country, the nuclear programme which up to a short time ago consisted of two reactors, suffered a setback when it was decided that the capital expenditure was too great to be considered at the present time, and the programme was reduced to one, now under construction in the suburbs of Stockholm for district heating and power generation. The Swedish paper said that hydro power at present covers almost all the electrical needs of Sweden, and the water reserves were so regulated to be able to meet all the daily and weekly variations in load, and most of the yearly variations. Thermal power is only provided to meet what remains of the yearly peak load. The remaining hydro-electric resources are being developed in step with the rise in

electrical consumption, and hydro-electric power will probably be able to deal with the rise in demand during the next 15 years. The principal Swedish paper went on to say "From the first half of the 1970s the annual utilisation time for thermal power production will grow sufficiently long to make possible the economic use of nuclear power. On the other hand, the abundance of hydro power during the summer will at first keep the utilisation period for nuclear power down to about 5,000 hours a year."

In Western Germany, a cautious view was taken of the present state of the economics of nuclear power. It was stated that the Federal Republic was the main producer of hard coal in Western Europe and besides large reserves of lignite and some crude oil and natural gas within her own territories, there was also a considerable amount of hydro power still untapped. Thus Germany had no urgent need for nuclear power, and a significant phrase appears in the main German paper "As things stand today, there is no one type of power reactor which may be considered as the only reasonable choice. Also, there is no one type which today fully meets both the technical as well as the economic requirements of modern power stations. Therefore under the circumstances prevailing in the Federal Republic no nuclear power station today is in a position to compete successfully with a conventional station." This unbiased review of the situation may well be thought to be of particular value.

Turning eastwards, in Poland, it was stated that the importance of hydro-electric development in the Polish power system was very great, but this was due only to its potentialities for providing peak power. The full economic utilisation of Polish resources would result in an annual production of 13,000 GWh per annum. It was thus expected that hydro-electric development would take place in step with an immediate programme for greater conventional station building, coupled with a future programme for nuclear power which estimated that about 800 MW will be installed by 1970, with a further 1,000 MW by 1975. At present a research programme involving experimental reactors is under way.

Remaining within the eastern bloc, an interesting paper from Rumania showed that while there are ample coal deposits and hydro-electric resources, particularly in the harnessing of the Danube, it seemed that towards 1970 nuclear power would begin to be required, and it was estimated that by 1975 about 10 to 15% of Rumanian power would come from nuclear sources. Nevertheless, it was thought that even by that date nuclear plant would be more expensive to construct and to run than the hydro-electric installations on the Danube which by then would be in commission; but power from the atom might be competitive at that time, with smaller hydro-electric installations, involving higher specific capital cost.

Another European country in which the energy at present is developed very largely from hydro-electric plants is Spain. The Spanish papers showed that hydro-electric energy in that country is cheaper than that in many other parts of the world, and, as an example, mention was made of the 600 MW plant at Aldeadavila where it was expected that when the plant was in operation, in 1960, the energy would cost not more than 3 or 4 mills.

It was estimated that the hydro-electric reserves in Spain now amounted to 44,000 GWh per annum, and this figure was greater than that which had been assumed so far. It was thought that 1970 would see the exhaustion of conventional resources in regard to meeting the increased demand which would have arisen by that date, and thus the Spanish Government felt that it was desirable to have nuclear plants available by 1964 or 1965. Thus a programme of research had been instituted and an experimental reactor had been set up to enable experience to be gained in nuclear power development.

Turning away from Europe, in Australia it was made clear that hydro-electric development was severely limited, and could provide only a fraction of the power needs over the next 50 years. Ample coal reserves were available, but nevertheless it was thought that long-term developments would need nuclear power; and a research programme of a highly comprehensive nature had been established.

In Japan the gradual utilisation of all remaining hydro-electric reserves was shown by a table given in the leading Japanese paper. It indicated that the installed capacity in 1956 included 6,793 MW of hydro-electric plant and 3,474 MW of thermal plant, while by 1962 hydro-electric plant would account for 10,480 MW and thermal plant for 8,670 MW; and in 1975 the hydro-electric equipment would have risen to near its maximum at 20,000 MW with thermal power generation rapidly catching up at 16,700 MW. The Japanese view was that with increasing reliance on imported coal and oil it was desirable to commence a nuclear power programme as soon as possible. By 1975 the total energy requirements of the country would have to be supplied by fuel nearly half of which would be imported, in the absence of nuclear power. Thus it was thought that with an advanced "Calder Hall" type of reactor nuclear power generation was already approaching an economic basis, and Japan was therefore embarking on a considerable nuclear power programme.

A paper by Dr. Homi J. Bhabha of India provoked much comment, and he also gave a summarising lecture on the use of nuclear power in underdeveloped countries. In his paper on the Indian power programme in particular he showed that the total hydro-electric potential of India was estimated at between 35 and 40 million kW, while the coal reserves amounted on a conservative estimate to about 40,000 million tons. The paper showed that by 1986 at least 10 million kW of installed capacity according to one form of estimation or 85 million kW according to another estimate would have to be provided by sources other than hydro-electric capacity, assuming that by then all available water power would be harnessed.

Dr. Bhabha gave some interesting figures for the cost per kilowatt of a number of leading hydro-electric projects in India. These figures showed that in general the cost per kilowatt was over £130 and that the cost was gradually rising. The harnessing of the last 5 or 10 million kW of hydro-electric potential might be so expensive as to make it cheaper to supply the same capacity from other sources. Summarising the projected power development in India, Dr. Bhabha showed that in the second five-year plan to end in 1961 the thermal stations would supply 3·88 million kW and the hydro stations 3·06 million kW, while by the end of the third five-year plan thermal power would account for 4·9 million kW, hydro 9·1

kW and nuclear power 1·0.

Dr. Bhabha was alone among those concerned with nuclear power in under-developed countries in thinking that this type of power was at present almost economic when compared with other forms of power generation.

In his lecture to the conference on the need for atomic energy in under-developed countries, Dr. Bhabha first showed that nuclear power would undoubtedly be uneconomic unless it was connected into a grid system where the load was sufficiently large to allow it to take a steady base load with a high load factor. Moreover, with the cost per kilowatt of something like 1½ to 2 times the present cost per kilowatt of other sources of power, most under-developed countries could not afford nuclear power in any case. The lecture included a table which attempted to estimate the absolute reserves of all forms of energy production resources divided into broad areas of the world.

Dr. Bhabha thought that India and South America might well form exceptions to the general rule that nuclear power at the moment could not be suitable from the economic standpoint for under-developed countries; but at the conference we heard some disagreement with the views he had expressed. Particularly in regard to India, it was felt that the financial position of that country made it impossible to contemplate the large capital expenditures needed for a nuclear power programme for very many years to come.

Space does not permit us to mention all the other national nuclear programmes in relation to the hydro-electric and solid-fuel resources of the countries concerned, but the notes set out above indicate the trends.

It was made clear, as stated at the commencement, that there is still much to be learned about nuclear power both from the economic and technical viewpoints. From the economic aspect, the cost of nuclear power, even in the most advanced country (at present Great Britain) will not be competitive until 1963 and then it will only become marginally competitive with thermal costs. Sir Christopher Hinton, the Chairman of the Central Electricity Generating Board, has stated publicly in recent years that in Great Britain it may well be necessary to reconsider the nuclear plant programme in 5 to 10 years' time unless costs can be reduced or the general load factor raised, so as to enable nuclear plants to be given a sufficient proportion of the national load to enable them to operate economically.

On the technical side, there is still no universal agreement as to the best type of power-generating reactor. There is a broad division between the British and French viewpoints that the natural uranium gas-cooled reactors (similar to those at Calder Hall but more advanced in design) offer reasonable prospects of gradual improvement in efficiency and decrease in cost; while on the other side of the Atlantic and also in the U.S.S.R., many experiments with different types of enriched uranium reactors, either of the pressurised-water or boiling-water types are under way, and enormous sums of money are being spent. It is obviously still open to doubt as to which type of reactor will ultimately prove the best for universal application; but what is not open to doubt is that hydro-electric power is, and will always be, the best partner for the nuclear power station.

New Zealand Annual Report

The Annual Report for the New Zealand Ministry of Works for the year ended March 31, 1958, contains, as usual, much interesting information on hydro-electric progress. The Engineer-in-Chief, Mr. C. W. O. Turner, states that engineering work on electric power projects during the year rose to a very high production level. The very considerable activity in this field is reflected in record expenditure, the amount actually expended by the Department being nearly £17 million, or £5 million more than for 1956–57. Coincidentally there was a greater proportion of this money spent on production of power from steam than on power from water. The exceptional increase in rate of expenditure represented a peak that was influenced to an extent by high levels of expenditure overseas on installed plant for the recently completed 180 MW steam station at Mercer and the 69 MW geothermal power station at Wairakei.

Concurrently with the construction of these steam stations, however, development of the hydro-electric potential of the Waikato River proceeded very satisfactorily on three stations, Atiamuri, 63 MW; Ohakuri, 84 MW; and Waipapa, 51 MW; to the extent indeed that it was anticipated that Atiamuri might be completed several months ahead of schedule. Provision has been made in the civil-engineering works at Atiamuri and Ohakuri to install one additional generating unit at each station; the installed capacity of the stations may thus be increased to 84 MW and 112 MW respectively.

Investigations of further hydro-electric projects both in the North Island and in the South Island proceeded expeditiously. In the South Island the investigations of Benmore were completed and design of that project was well in hand; meanwhile preliminary investigatory works were initiated at other power sites on the Waitaki River, notably Waitangi and Maryburn. As the result of investigations it became evident that completion of the Waikato schemes would by no means complete hydro-electric power development in the North Island, and in the Rangitaiki River and the Upper Waikato developments alone some 750 MW of power potential exists—equal to the power to be obtained from the Waikato River below Taupo.

From page 424

17 L. Deffet and J. Demarque, Resultats recents de travaux en carrière, *Explosifs*, 2, 1956, s. 49.

18 G. Otto, Die Ausbreitung der Erschütterung um bergmännische Sprengladungen, *Bergbautechnik*, 6, December 1956, s. 659-662.

19 E. Hahn, Die Anwendung der seismischen Magnitude und Siesmizität, *Freiberger Forschungshefte*, C. 25, Akad. Verlag, Berlin, 1956.

20 A. Sander, Das Problem der seismischen Greuzschichtwelle, *Freiberger Forschungshefte*, C. 26, Akad. Verlag, Berlin, 1956.

21 U. Langefors, H. Westerberg and B. Kihlström, Schadenwirkungen von Bodenerschütterungen durch Sprengungen, *Nobel Hefte*, 23, 1957, p. 220.

Gabion Towers for River Closure

New Zealand engineers employed gabion towers for the diversion of the Waikato River for the construction of the Ohakuri scheme. The closure was rapidly and easily effected by a small team of men

DIVERSION of the Waikato River for construction of the 112 MW Ohakuri scheme was recently completed by the New Zealand Ministry of Works in an operation notable chiefly for the ease and efficiency with which an unusually small team of men and machines effected closure.

The river was 100 ft. wide at the closure point, with an average flow of 7,000 cusecs. Use of control gates at the Lake Taupo headwaters reduced this to between 4,500 and 3,500 cusecs over the critical period, and part of the river was already flowing through the diversion tunnel on the right bank when work began on the final stages. A closure barrier 20 ft. wide on top, of varying cross-section, but with a maximum depth of 55 ft. and bottom width of 200 ft. maximum, was decided upon, to contain an estimated 10,000 cu. yards of rockfill. Some 8,000 cu. yards were placed at leisure, leaving a gap of 40 ft. to be dealt with during closure. Large boulders were stockpiled on the edge of this gap, on the left bank, and on the right bank gabion towers had been prepared some weeks before.

The gabions were made by hand-packing selected rock into steel-mesh baskets 3 ft. square in cross section and 10 ft. long. Baulks of timber were used on the bottom corners of each to give rigidity to the whole, and each gabion weighed approximately two tons. They were further secured in blocks of 16, giving a total weight of 32 tons.

Plant used consisted of two shovels of 2½ cu. yard capacity supplying 10 Euclid trucks on a run of approximately 500 yards, two D-8 bulldozers with blades, and two fitted with Hyster winches.

The final operation began at 5 a.m., as soon as the

Fig. 2. A later stage in the closure operation showing a gabion tower about to topple into the gap

Fig. 1. Gabion tower being pulled into the river channel

Fig. 3. Closure complete; downstream cofferdam and diversion tunnel outlet

river level had begun to fall, and by 8.30 a.m. the gap had been reduced to 18 ft., at which stage the rapidly increasing velocity of the current was sweeping away even quite large rocks. The gabion towers were then rolled into place, by winching from the left bank. This produced immediate and spectacular results, enabling Euclids already loaded with single gabions to deposit these in gaps between the 32 ton blocks. Effective closure of the last critical gap was thus attained within a matter of minutes. Rockfill was then bulldozed over and around the gabions, and by 10 a.m. the planned closure barrier was complete.

Subsequently this cofferdam was blanketed with alluvial materials and built up to a height of 70 ft. with a width of 40 ft. on top. A downstream cofferdam was completed during the same period about 900 ft. downstream, and dewatering was effected by a barge fitted with pumps and anchored between the two cofferdams. Combined leakage at about 1,000 gallons a minute is considered minor, and the Department is pushing ahead with excavation in the river bed preparatory to placing the 300,000 cu. yard earth dam required for this project. This dam will be 800 ft. wide at the base with a structural height of 160 ft., and a crest 260 ft. long.

The Ohakuri diversion was the sixth on the Waikato river, and at time of writing preparations were well advanced for the seventh, at Waipapa (50 MW, also an earth dam).

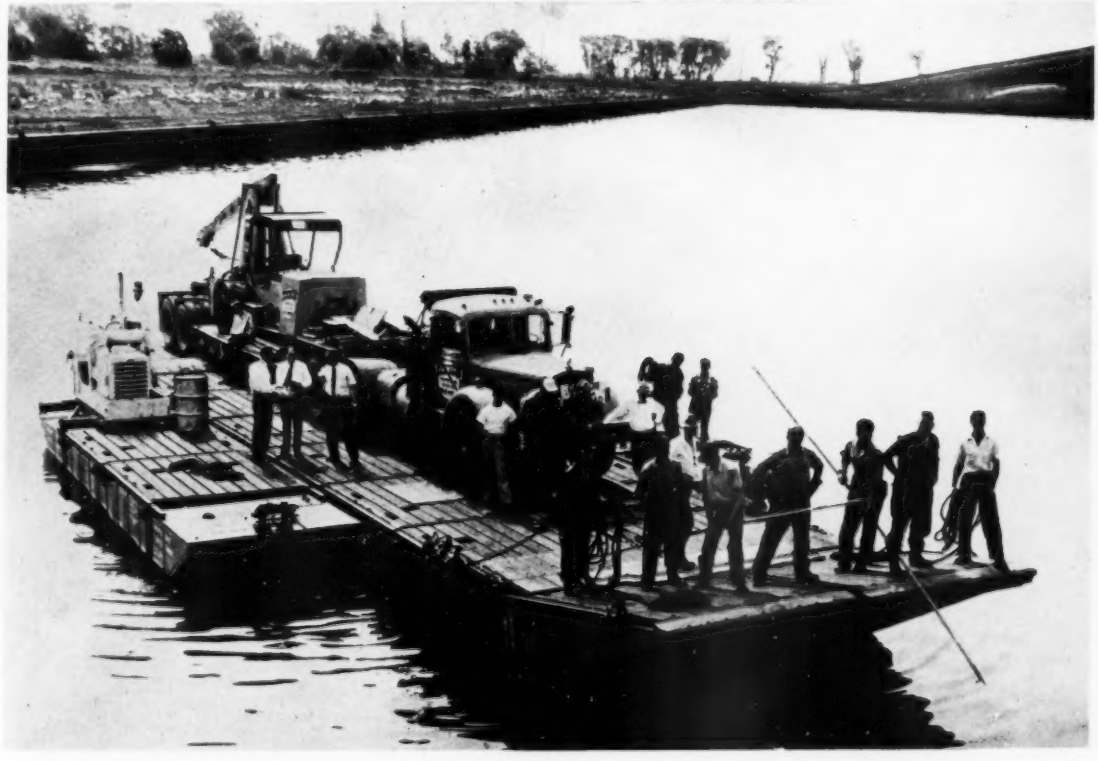
Other projects now in hand on the river include Atiamuri (84 MW), nearing completion, and two schemes outlined in a recent Government statement. These are a 70 MW station at Aratiatia specially designed by the Ministry of Works to preserve the scenic beauties of this area, and a new peak-load power house at Maraetai with a final installed capacity of 180 MW. The first installation for the latter, to be completed by June 1963, will be 72 MW, and the station will make use of the existing Maraetai dam which already serves a 180 MW station.

Investigation drilling is now in progress on both sites, and a small construction camp has been built at the former. At Atiamuri preparations for flooding the lake are well ahead, and commissioning the first machine may prove possible by the end of this year, several months ahead of schedule.

Uniflotes for Ferry Building

A LITTLE over a year ago we described* the Storey Uniflote and its many uses in the civil-engineering world. Since then it has been leaving the production line of Thos. Storey (Engineers) Ltd. at Stockport for service in many parts of the world. The landing-stage described in our previous article is now fulfilling its task at Nkata Bay, Lake Nyasa, and Uniflotes are in operation in South America for bridge positioning and in Canada for submarine pipeline drilling, with clam shells, shovels and drilling equipment operating from the Uniflote raft decks. In addi-

* WATER POWER, October 1957, p. 397.



NO OTHER COMPRESSOR

—piston or rotary—delivers so much air for its size and weight

Compare the difference in size between the VT4 and an average rotary compressor in the 125 c.f.m. range.
125 cfm
160 c.f.m
Atlas Copco

PACKAGED POWER IN THE ATLAS COPCO VT4— THE WORLD'S LIGHTEST 160 c.f.m. COMPRESSOR

The VT4 is over 20% lighter and 25% smaller per c.f.m than any machine, piston or rotary, in its range.

Lighter and smaller than some machines with a free air delivery of only 60 c.f.m.—the VT4 has taken power weight ratios into a new dimension.

Powered by a Deutz diesel engine the VT4 gives an unequalled c.f.m./h.p. ratio, with fuel economies which offer a saving on any contract.

The VT4 is the first of a series based on major changes in design and production methods. For example, it is the only machine with a single welded unit, which incorporates the crankcase, bellhousing and cylinder ducting.

Basic simplicity in design eliminates maintenance and overhaul problems—local mechanics anywhere can service this machine.

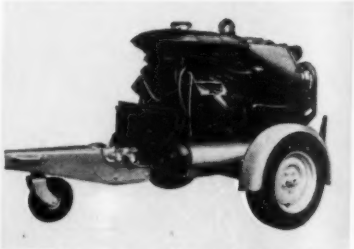
Unscrew one nut and all four valves in the low pressure cylinder can be removed. Loosen three bolts and the complete engine-compressor unit lifts out.

The VT4 is 100% air-cooled—starts on the button and works with equal efficiency anywhere in the world.

The VT4 is easier to load with its low weight and built-in lifting eye—easier to tow with its two wheels and torsion bar suspension.

Manhandling on site is a simple operation with a machine weighing less than 21 cwt. and fitted with a pivoting nose wheel.

All instruments and controls are operated from a central dashboard.



The VT4 is compactly assembled under a canopy which can be completely stripped in a few minutes to give maximum access.

THE *NEW* VT 4

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent, or write to Atlas Copco AB, Stockholm 1, Sweden

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tion, the armies of the Western Union are commencing to equip themselves with Uniflote components.

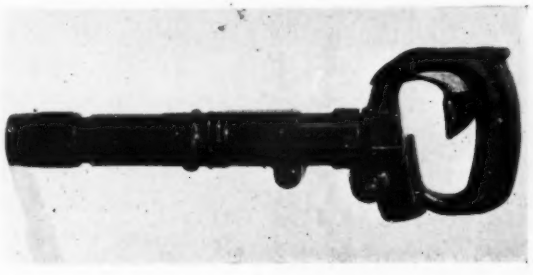
Two further applications of the Storey Uniflote have now been developed and are in course of manufacture. The first is a buoyant Uniflote bottom-dump tipping skip for the building of breakwaters and for marine dumping of all types, which, being flat-bottomed, can also be discharged by grab or other suitable shovel equipment. The second is an infinitely variable mobile floating scaffolding, for the repair of ship sides, particularly the raking faces of the bows and sterns of ocean-going liners.

At a recent demonstration which we were privileged to attend, Uniflotes were used to form a powered ferry. This particular ferry, composed of eight Uniflotes, four articulating ramps, two bows, two sterns and two harbourmaster power units, can be assembled by one commander and 24 men in ten minutes. The powered Uniflote raft was brought abreast of the bridge-end and secured to the bridge Uniflotes with articulating connecting links, and the ramp sections were then connected from the bridge-end to rest freely on the Uniflote decks. A mobile crane then proceeded down the ramps and on to the Uniflote raft, where it was slewed round, the links cast off and the ferry powered away to land the crane on the banks of the reservoir, down the articulating ramps. The manoeuvre was repeated, but on this occasion, the unit conveyed was a six-wheel drive pneumatic AEC chassis mobile crane. Throughout the day, the Uniflote raft proceeded to power along the reservoir, and a BEA helicopter made a series of routine landings and take-offs, thus showing that, even with this small platform, the equipment, in conjunction with helicopters, has great possibilities for the civil-engineering contractor.

Demonstrations were recently carried out by Thos. Storey (Engineers) Ltd. with their powered Uniflote rafts on Lake Ontario, and in the accompanying illustration is shown a 57 ft. low-loader carrying a bull-nosed crane—a total all-up load of 40 tons.

New Version of C.P. 7½ lb. Rock Drill

Designed as a miniature rock drill weighing only 7½ lb., the new version of CP9, known as the CP9F, now being produced by The Consolidated Pneumatic Tool Company, of 232, Dawes Road, London, S.W.6, is a fully self-rotating percussive hand drill with a wide range of application from drilling plug holes for survey points, secondary blasting, fixing and securing of installations, to chipping and chasing and sample cutting.



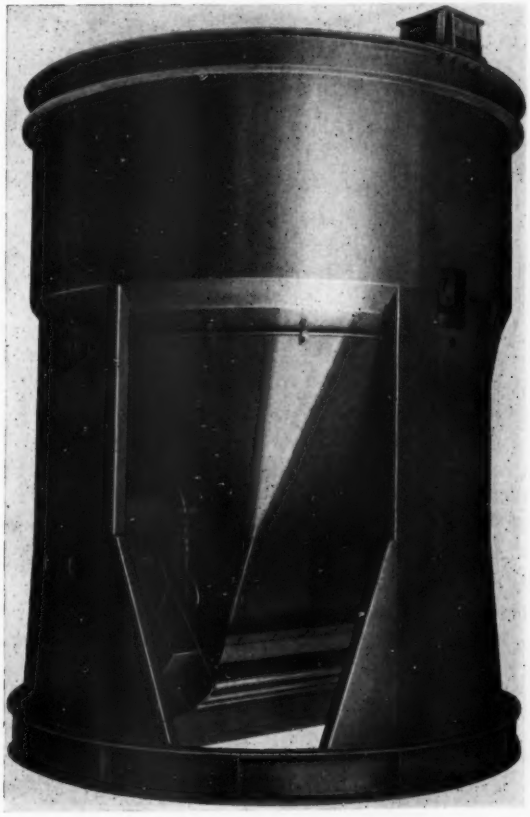
Features include a new rotating chuck, a quick-change steel retainer for rotating drill steels or non-rotating chisels, a new type of valve designed to provide maximum drilling speed and powerful rotation with low air consumption, a built-in oiler, and a right or left-hand exhaust, threaded so that a blower hose may be used where necessary. The cylinder, cylinder bushing and fronthead are steel forgings, all working parts being of heat-treated alloy steel machined and ground to fine limits. The cylinder bushing is renewable and the graduated throttle valve has a leakproof renewable rubber seat.

Hollow rotating drill steels have been adopted to enable a jet of air to be directed to the drill point to keep it cool and remove dust and chippings. Both rotating hexagon-shanked drill steels and round-shanked non-rotating chisels are retained by four balls in the rotating chuck. Steels are released by pulling back the spring-loaded chuck sleeve and withdrawing the drill or chisel.

The overall length of the tool is 14½ in. and it may be supplied complete with a carrying case which houses a length of ⅜ in. hose, steels and other accessories.

Hydraulically Operated Buckets at Grande Dixence

A new type of self-energising hydraulic bucket, designed and produced by Blaw Knox Limited, 90/94 Brompton Road, London, S.W.3, is now in use at



Emergency in Norway—new Atlas Copco VT4 provides the answer

An outbreak of fire at a hydro-electric plant under construction high in the mountains at Svelgen, Norway, resulted in the total destruction of the compressor installation.

As it was vitally important to maintain an adequate supply of compressed air, an urgent order for two new machines was sent to Atlas Copco, Oslo. Less than three hours later two VT4 compressors were delivered to Oslo's Eastern Railway Station.

The real obstacles were encountered during the last two stages of the journey. As the machines had to be taken by aerial ropeway and finally by helicopter, they were dismantled—a simple operation with the VT4.

Within hours of reaching the site, the VT4 machines were assembled and supplying air to the numerous rock drills and pneumatic tools needed for driving the rock tunnels. This operation proves the value of the remarkable power/weight ratio of the VT4—unrivalled by any other manufacturer.

More power, less weight

Atlas Copco's new VT4 compressor was the ideal machine for this sort of job, because no other portable compressor combines so large a power output with such light weight and small size. The

One of the VT4 machines already assembled

VT4 is the lightest and smallest portable in the 150-160 cfm range, piston or rotary. It gives more cfm per hp than any other, piston or rotary. It is 23-55% lighter per cfm and 26-65% smaller per cfm than all others of its class, piston or rotary. It is 100% air-cooled for use anywhere, any time: thus, on this operation, the fact that the VT4 is independent of other cooling was of great value for operation high in the Norwegian mountains. Air temperature is right for maximum tool efficiency. Outstanding simplicity of design means no specially trained mechanics are needed.

A complete range of compressed air equipment

Atlas Copco manufactures portable and stationary compressors, rock-drilling equipment, loaders, pneumatic tools and paint-spraying equipment. Sold and serviced by companies or agents in ninety countries throughout the world.

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent or write to Atlas Copco AB, Stockholm 1, Sweden or Atlas Copco (Great Britain) Ltd., Beresford Avenue, Wembley, Middlesex.

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the Grande Dixence dam in Switzerland. These buckets, which do not require a hydraulic or air line connection for operation of the clamshell roller gate, are available in sizes ranging from 3 to 8 cu. yards capacity. They are simple to operate and they will open and close quickly with any load of concrete. The hydraulic system includes two-compartment type accumulator rams and a spring-loaded pull release cord or chain. Sufficient hydraulic pressure can be stored for two complete operating cycles and the accumulators can be recharged simply by setting the bucket down and raising it again.

Fuller Electric's Diamond Jubilee

Fuller Electric Limited, Walthamstow, London, E.17, recently celebrated their 60th anniversary, and the occasion afforded us a welcome opportunity to visit their works and to see something of their achievements, mainly in the field of large power transformers.

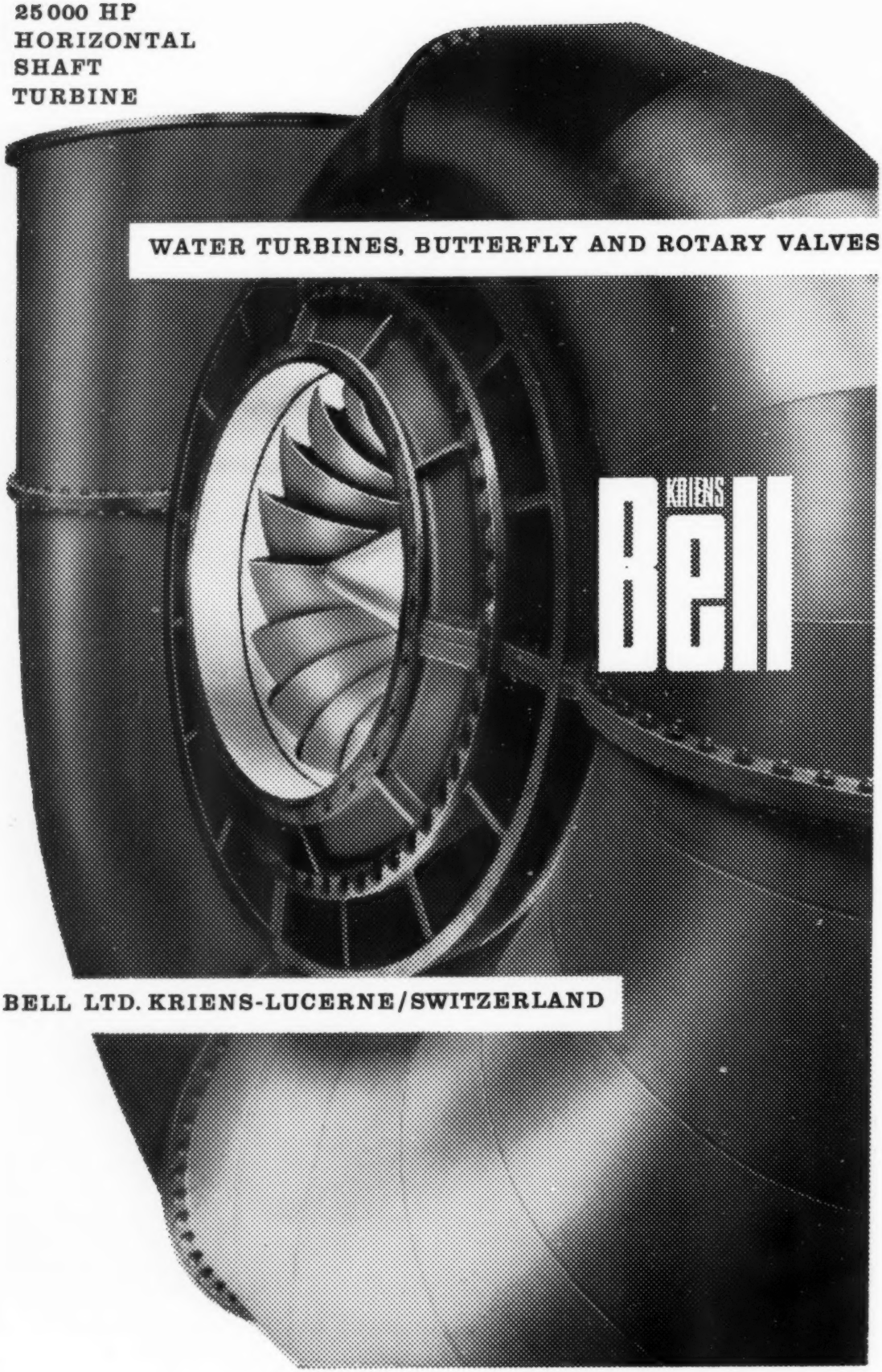
Fuller Electric Limited originates from the Fuller Wenstrom Electrical Manufacturing Company, which was formed on July 1, 1898. Mr. J. Leslie Fuller had earlier been appointed sales representative of Allmänna Svenska Elektriska Aktiebolaget, and the Fuller company has been British licensee for ASEA products from its foundation to the present day. In April 1957 the share capital of the company was acquired by the Brush Group, and subsequently, by a merger between the Brush Group and the Hawker Siddeley Group, Fuller Electric Limited became a member of the Hawker Siddeley combine. At the same time agreements were entered into to maintain the technical connection with the ASEA. This connection with the Swedish firm has in no way precluded Fuller Electric Limited from carrying out its own engineering, and in fact for many years the company has maintained its own independent design staff.

Several points impressed us in the design and manufacture of the company's large power transformers. The first was the care taken in the selection, annealing and varnishing of the core laminations and in the building of the cores. Secondly, unusually thin wrapping paper is used for the conductors, giving correspondingly more layers for a given thickness of insulation and more effective overlapping. Thirdly, tapping windings are designed as far as possible to maintain complete magnetic balance irrespective of which tapping is in use. Fourthly, all windings are precompressed under a 200 ton hydraulic press to a pressure somewhat in excess of that to which they would be subjected by short-circuit with sustained voltage. The windings are subsequently locked in the transformer under this pressure, so that in the event of short-circuit they will not move.

During our tour we saw one of four 120 MVA 275/132 kV transformers under construction for the British Central Electricity Generating Board, who have also ordered two 180 MVA 275 kV units. We

The shop devoted to the manufacture of on-load tap changers

25 000 HP
HORIZONTAL
SHAFT
TURBINE



also noticed some of an order of seven 15/18·3 MVA 230 kV transformers for the State Electricity Commission of Victoria, Australia. Fourteen similar transformers are already in service in Australia. An order for six 45 MVA 230 kV units is being executed for Canada, following two 41·6 MVA 230 kV units already in service. Medium-sized transformers and small distribution units naturally also form staple lines.

Since 1929, Fuller Electric Limited have made a speciality of on-load tap changers, and their success in this field has been noteworthy. Transformers totalling over 27 million kVA have been fitted with Fuller on-load tap changers, and these include large numbers supplied to other transformer manufacturers.

Another speciality is the manufacture of Schrage-type a.c. commutator motors in sizes up to 50 h.p.

Elsewhere in this issue we have mentioned the preliminary tests just carried out on the laying of the 160 MW 220 kV d.c. power cable across the English Channel. Fuller Electric Limited, as representatives of ASEA, have received the order for the a.c./d.c. converter plant to be installed in the English terminal at Lydd.

Abstracts from the World Technical Press

A New Design for Reinforcing High-Pressure Branch Pipes

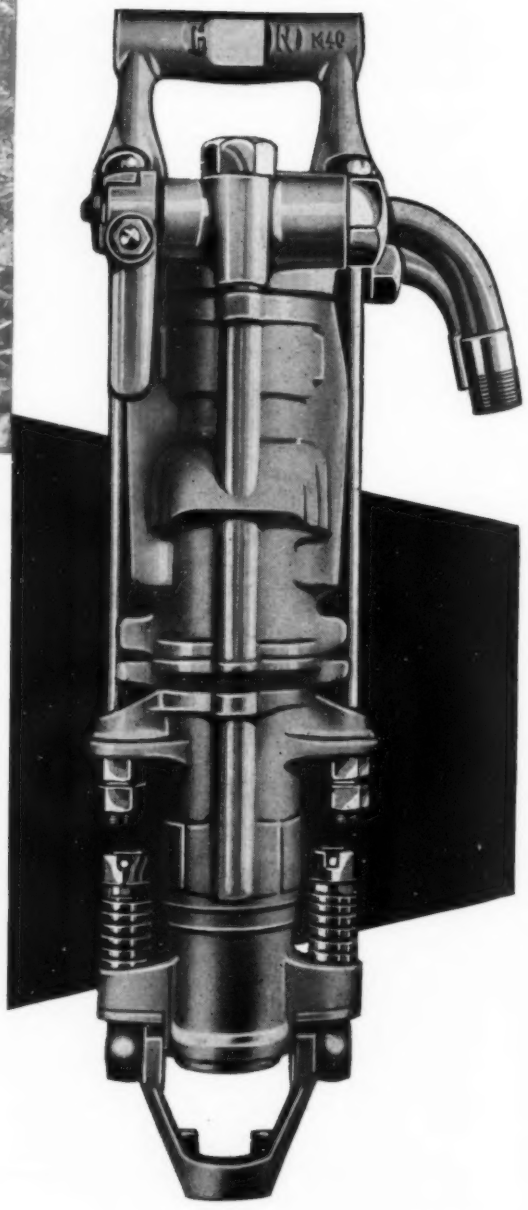
Distribution and branch pipes are essential in high-pressure plant because if a separate pressure pipe feeds each turbine, the friction losses increase considerably in comparison with a single and larger penstock of the same weight. The distribution pipe is usually situated very near to, or even inside, the power station, a high margin of safety should be allowed in the design and there is no reason why higher stresses should be tolerated in the distribution piping than in the pressure pipe. All calculations have to be checked by measuring stresses on models as well as actual plant, and Escher Wyss have carried out a series of tests using mechanical tensometers and electric strain gauges to measure the stresses. As a result of these tests, various designs have been obtained, one of which is the reinforcement of a Y-pipe by an elliptical rib situated at the plane of intersection and two collars at right angles, formed by annular segments of approximately constant cross-section. In another slightly larger version of this design, the cross section of the reinforcing collars is partly T-shaped in order to reduce the stresses at the outer edge of the collars. A further evolution showed that the transverse ribs could be replaced by an internal stress band, thus reducing the amount of material required and simplifying the construction. When a branch pipe is of much smaller diameter than the pressure pipe, a closed collar made of cast steel may be more satisfactory. Cast steel can be machined more easily; it enables better hydraulic shapes to be obtained and a smoother, more gradual intersection is possible between the collar and the pipe. Measurements and tests have shown that in conventional methods for counteracting stresses, the reinforcing materials are not always correctly placed. High stress peaks in the plane of symmetry result from a large bending moment, and although stresses are distributed irregularly over each cross-section of the collar, they vary around the circumference. A new patented method of strengthening has been developed which eliminates peaks, requires less material and reduces the cost. The stresses occurring in the line of intersection of two pipes are transmitted to the strengthening collar which lies in the plane of this intersection. The resultant of these forces between the beginning of the collar and the point in question is determined according to size, direction, and position at various points along the line of intersection. The cross-section of the strengthening collar passing through this point at 90° to the resultant is made symmetrical to the resultant and proportional to its size. The strengthening collar then becomes a unit of constant strength which is only subjected to normal stresses. From a practical point of view, it is desirable that the collar should be of constant thickness and, if the above principle is followed, it is then found that the final shape of the collar is in the form of a sickle which is symmetrical to the line of intersection at the crown inside the branch piece and at the apices. Apart from important reductions in weight and cost, the new design has smaller overall dimensions resulting in less excavation and concrete work, easier and cheaper transportation and a higher margin of safety against rupture. (*Escher Wyss News*, Vol. 30, 1957, No. 3; Vol. 31, 1958, No. 1.)

Transformer Engineering

This article is a reprint in Slovenian of the lecture given by the author on November 6, 1957, before the Oesterreichischer Elektrotechnischer Verein in Vienna (Austrian Electrotechnical Association), on the evolution of transformer design and construction from the small "dry" transformers of fifty years ago to the present 200 MVA units. The original German text of the lecture is appended. (Milan Vidmar, Ljubljana, *Elektrotehniški Vestnik*, No. 1–2/1958, p. 1, 6 pp.)

Saint-Martin-Vésubie Development

The extension of the prewar Franco-Italian frontier to the ridge line of the Maritime Alps, about 60 km. north of Nice, gave France the possibility of harnessing, without any limitation, the waters of the Vésubie river and of its tributaries—the Boréon, Madone des Fenêtres, Spaillard and Gordolasque. The smallness of the catchment area is offset, however, by exceedingly steep gradients which enable the power water to be collected through relatively short tunnels. For example, the average slope between the intake and the tailrace of the St.-Martin-Vésubie plant is 70 and 84 m. per kilometre for the Boréon and Madone des Fenêtres respectively. The region has a heavy rainfall. General characteristics are as follows: total area drained 103 sq. km.; mean annual flow 4·63 cu. m. per sec.; installed discharge 8 cu. m. per sec.; maximum gross head 730 m.; installed capacity 57,200



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kVA; output 172 million kWh; transmission voltage 150 kVA. In plan, the general layout of the water-supply system presents roughly the shape of a Y, the left wing of which, 6,560 m. in aggregate length, collects the waters of the Salèzes, Boréon and Madone des Fenêtres, and the right wing (6,900 m.), those of the Gordolasque and Spaillard. From the junction of the two wings at a spot called "Point Triple," a further tunnel section of 1,540 m. leads to a ridge on which are sited the surge tank, the gate chamber and a penstock 1,830 m. long, the latter forming the leg of the Y, and feeding the St. Martin-Vésubie power house. The only reservoir of the whole development, no more than 115,000 cu. m. in capacity, is created in the narrow rocky gorge of the Boréon at a spot called Ciriégia by a thin arch no more than 1,000 cu. m. in volume, 14 m. in height and having a developed crest length of 52 m. On the right wing is a 28 m. gravity section extending into 105 m. rockfill embankment. The Ciriégia reservoir, which also receives the water of the Salèzes stream, will, by means of weekly releases, back up the supply system of the development at critical low-water periods. All the five intakes of the system are equipped with efficient sand traps. The tunnels, 14,350 m. in aggregate length, are driven throughout in horseshoe cross section, with a lining varying in accordance with the quality of the rock. In perfectly sound sections, the invert only is concreted, whereas in average quality sections the whole horseshoe cross section is lined, and doubtful sections are lined so as to form a circular inner cross section. The surge tank, of the throttled type, consists of a vertical shaft 2·5 m. in diameter, by 35 m. in height, surmounted by a 75 m. long tunnel section acting as expansion chamber. The valve chamber houses, in addition to the butterfly valve, the hoist and ancillary equipment of the inclined shaft. Out of a total length of 1,834 m. of the penstock, the upper 1,625 m. is in the inclined shaft. This penstock consists of three sections of 650, 608 and 576 m. in length respectively, their corresponding diameters being 1·80, 1·65 and 1·50 m. and plate thickness 9 to 21, 19 to 34 and 32 to 42 mm. The inclined shaft will be served by a 15 ton trolley for material transport, running at 20 m. per min., and a personnel trolley running at 60 m. per min. and designed for carrying 12 passengers in addition to 4 tons of material. Following the geologist's advice, the project of an underground power house was discarded and the slope of the rock cliff which forms the left bank of the Vésubie river will be cut back to form a platform at a height above the river level sufficient to protect the plant from flooding. The power-house building will be an elongated structure no more than 11·6 m. wide inside, located between the control and administrative building upstream and the erection platform downstream, the latter also serving as a forecourt connecting with the access road and as a service deck for the transformers. The transformer bench will be sited between the power house and the river at the same level as the erection platform on an embankment built up with the help of the material cut from the cliff. More space will be saved by placing the switching station on the flat roof of the power house. The final siting and layout of the power house was also determined by the projected downstream plant at Roquebillières, which is to be operated by remote control from St.-Martin-Vésubie. The generating equipment will consist of two horizontal sets, each with a 28,600 kVA alternator running at 600 r.p.m. between two single-jet straight-nozzle Pelton wheels designed for a discharge of 2 cu. m. per sec. each, at a rated net head of 692·85 m. Civil-engineering work on this development started in the spring of 1956 and is proceeding at the present moment at all construction sites. Erection work, which began in October 1957 on the penstock and last January on the generating sets, is now in full swing and it is expected that the plant will be on the line in the first half of next year. (Elie Morenon, EDF, *Construction*, Vol. XIII, No. 5, May 1958, p. 129, 9 pp., 11 ff.)

Modern Trends in Hydro-electric Development

The most striking feature of recent hydro-electric projects is that they tend to be comprehensive in various aspects. They may embrace one or more river systems, and may serve many purposes in addition to power generation. In all cases, however, they are carefully co-ordinated with other available sources of electric power, such as coal-fired or nuclear power stations. Of particular interest to the power engineer is the emphasis placed on peak power generation, either by natural or artificial (pumped) storage schemes. This paper (No. 1326), which originated in the Sydney Division of the Institution of Engineers, Australia, also deals with the progress in the design of power plant and equipment as influenced by the above tendencies and by the search for more economical and novel solutions. A short paragraph is devoted to tidal plants. (W. Diesendorf, Dr. Tech. Sc. (Vienna), *The Journal of the Institution of Engineers, Australia*, Vol. 30, No. 4/5, April–May, 1958, p. 117, 8 pp., 3 ff.)

Electrification in Bulgaria

Following a historical survey of the development of electrification in Bulgaria during the past 80 years, the author emphasises the importance of hydro-electric power in the economic expansion of the country. By January 1, 1957, installed capacities had reached 41·5% in hydro-electric plants and 50% in coal-fired plants, the figures for output being 33 and 64% respectively. Since 1944, 11 dams have been built with an aggregate storage capacity of 1,900 million cu. m., and the storage to be created by new dams in course of construction will total 970 million cu. m. Sources of water power are unevenly distributed, being concentrated in the south-western region of the country. The rivers of the region (Struma, Mesta, Tundja and Maritsa) are characterised by steep falls, good levelling potentialities and small flows. (Nikola Ivanov, Deputy Minister of Electrification and Water Economy, Bulgaria, *Power Engineer*, Vol. 8, No. 2, April 1958, p. 66, 4 pp., 3 ff.)

Electrification in Yugoslavia

This article deals exclusively with Slavonia, that is to say the eastern part of the Croatian Republic, which until recently was still one of the most backward regions of the country from the point of view of electrification. Most of the energy supplied to consumers is generated in thermal plants (steam and diesel) and the development of water power is still in its infancy. Thanks to the activity of "Elektro-Slavonija," the state corporation in charge of electri-

fication, considerable progress was achieved between 1945 and 1957 but, as far as Slavonia is concerned, the enormous resources of the great rivers which form most of its boundaries, the Danube and its two major tributaries, Drava and Sava, appear to be still undeveloped. (Stjepan Kragujevič, *Energija*, Zagreb, Vol. 7, No. 5–6, June–July 1958, p. 166, 6 pp., 4 ff.)

NOTE.—The above journal contains two further articles of special interest, both dealing with 220 kV transmission lines. The first is a study of the most favourable types of towers and conductors (B. Markovčić and R. Škarica, p. 140, 3 pp., 4 ff.); the second describes the preliminary studies, the project and the construction of the Jajce-Zagreb line, as well as the procedure contemplated for replacing the two temporary 110 kV three-conductor systems by 220 kV systems. (R. Škarica and K. Fišer, p. 159, 7 pp., 6 ff.)

Building Large Dams

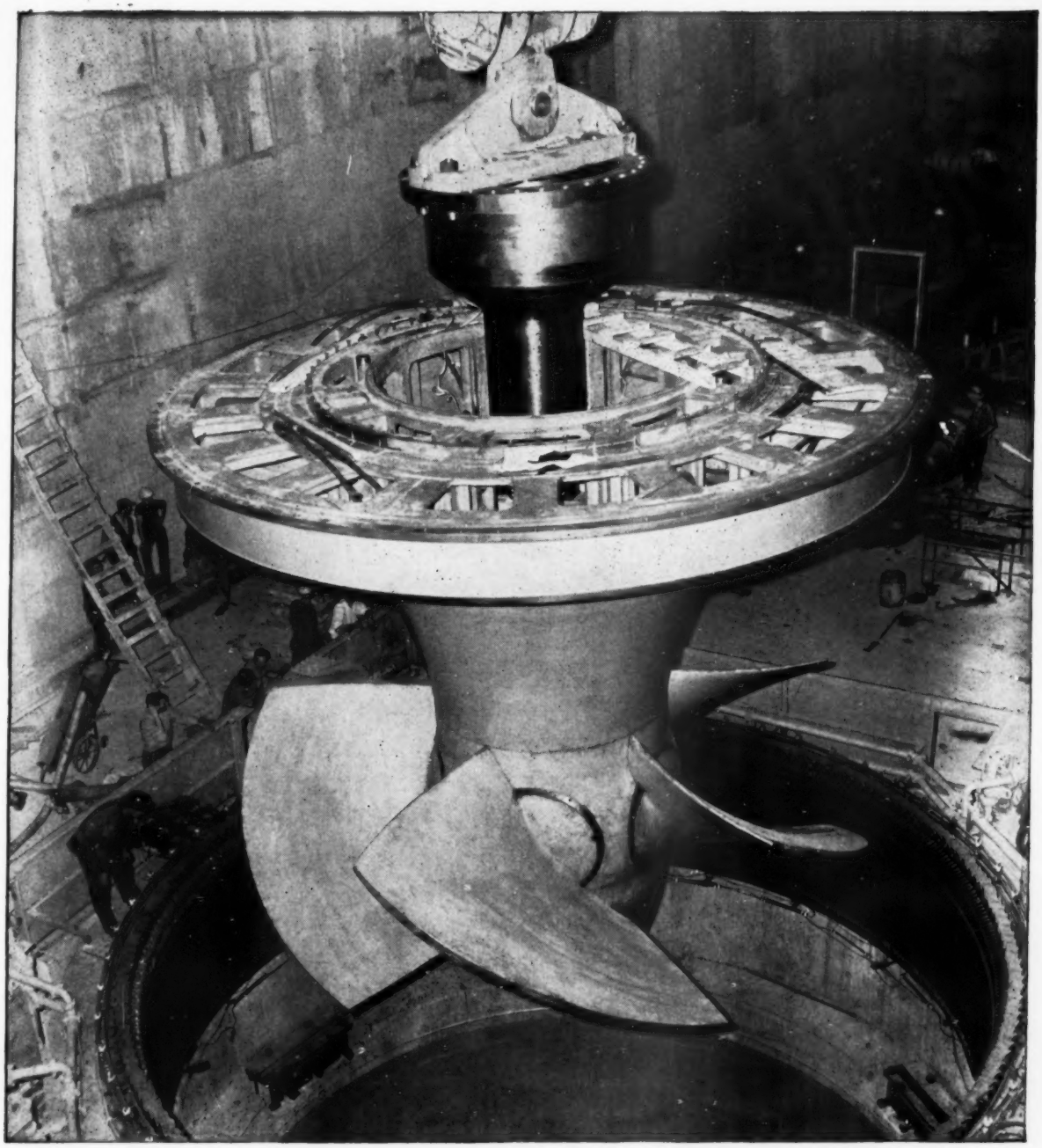
This paper was read on May 20, 1958, at the conference of "L'Industrie Française des Travaux Publics," and reviews at the outset the great progress achieved since the war in the construction of hydroelectric plants in Western Europe, the possibilities offered in the same sphere by undeveloped countries in Europe and overseas, and the evolution of construction methods which has taken place. In France, where the size of dams is to some extent restricted by a densely populated countryside and an abundance of roads and railways across valleys, designers are devoting special attention to the improvement of building techniques. The concrete gravity structure, still a rule with few exceptions 40 years ago, is practically now banned by French experts in favour of arch dams in narrow valleys (Tignes, Enchanet) and of multiple-arch structures in wider valleys. The author stresses the outstanding contribution made by M. Coyne to this evolution, which has led to stupendous economies in building materials. For instance, at the 150 m. high Tignes dam, the thickness of the arch at the bottom is no more than 43·5 m., while the normal profile of a gravity dam of the same height would have required a corresponding thickness of no less than 144 m. At the Tolla dam, now in course of construction in Corsica, the thickness of the 90 m. high arch varies between 1·50 and 2·43 m. at crown, and does not exceed 4·2 m. at the wings. The second part of the paper deals with construction techniques and concreting. The evolution of concrete distribution, from the chute tower to the belt-conveyor tower, cableway crane and tower crane, is described. The output of the tower cranes was greatly improved by increasing their number and setting up service bridges from which they could reach any spot on the construction site. At the Bort dam, record performances in concrete distribution were achieved by using travelling cranes moving on two concentric service gantries. In the preparation of concrete, the author advocates the use of fine sands and emphasises the importance of large-capacity hydro-separators which enable the sand particles to be separated into several basic sizes between $\frac{1}{10}$ and 3 mm.—sizes which can be subsequently blended according to requirements. The importance of efficient construction plants, which can be dismantled and moved to other construction sites, is particularly stressed, the Bort and Grandval plants being given as models. Thanks to all these technical improvements substantial economies can be obtained, not only through the reduction in volume of the necessary building materials and through lesser labour requirements, but also through the accelerated construction tempo. (Marcel Mary, Chairman of the French Committee on Large Dams, *Travaux*, Vol. 42, No. 287, September 1958, p. 843, 8 pp., 17 ff.)

Protecting Outdoor Substations

As the prime purpose of an outdoor substation is to ensure a reliable continuous supply of energy to the utilisation point, it is obvious that such substations must be provided with an efficient protective system. Reliability can only be achieved if the protection provided interrupts the flow of fault current and isolates the faulted elements so that the remaining sections of the system can continue to ensure service. This article describes the protective system adopted for the substation of a complex power system with five incoming lines and eight feeder circuits. The main feature of the protective arrangement is its division in overlapping zones of protection: transmission lines, busbars to incoming lines, transformers, busbars to outgoing lines, and feeders. Thus, faults occurring in any area or zone cause response of the protection relays in both that area and in the area with which it overlaps. (Stanley E. McDowell, *Allis-Chalmers Electrical Review*, Vol. XXIII, No. 2, Second Quarter 1958, p. 26, 6 pp., 16 ff.)

Refacing a Dam

This article deals with the repair work carried out on the downstream face of the 40-year-old Lake Creek dam, Troy, Montana, the original face of which had been badly damaged by lime deposits and by ice action. In addition to some of the tiers being entirely undermined, considerable leakage had developed through deteriorated horizontal construction joints along the full length of the dam. The structure is a gravity-type spillway block with a crest length of 265 ft. and a maximum height of 40 ft., and it has 6 ft. piers along the crest, and vertical gates between the piers. Restoration started with chipping, cleaning and shuttering of the downstream face. Washed coarse aggregate was placed in the forms and thoroughly rodded to ensure a uniform fill and point-to-point contact. The downstream face was then grouted up to the base of piers. In one case, it was necessary to remove and rebuild an entire pier. While pier repairs were in progress, the reservoir level was lowered to expose the upstream face of the dam, and chipping and cleaning proceeded as the pool dropped in height so that spillway crests, pier bases and a large part of the upstream face were ready for shuttering at about the same time. Internal grouting from the upstream face to restore deteriorated construction joints was completed before the dam was faced with new concrete. Grouting of preplaced aggregate in the dam crest and upstream face of the piers followed the joint sealing work. Upon completion of the construction work on the upstream face, internal grouting on the south abutment proceeded. This tricky repair job proved thoroughly efficient: in fact, after the reservoir had been filled no leakage could be detected through the face of the dam under full hydrostatic head. (*Engineering News-Record*, Vol. 161, No. 4, July 24, 1958, p. 44, 3 pp., 4 ff.)



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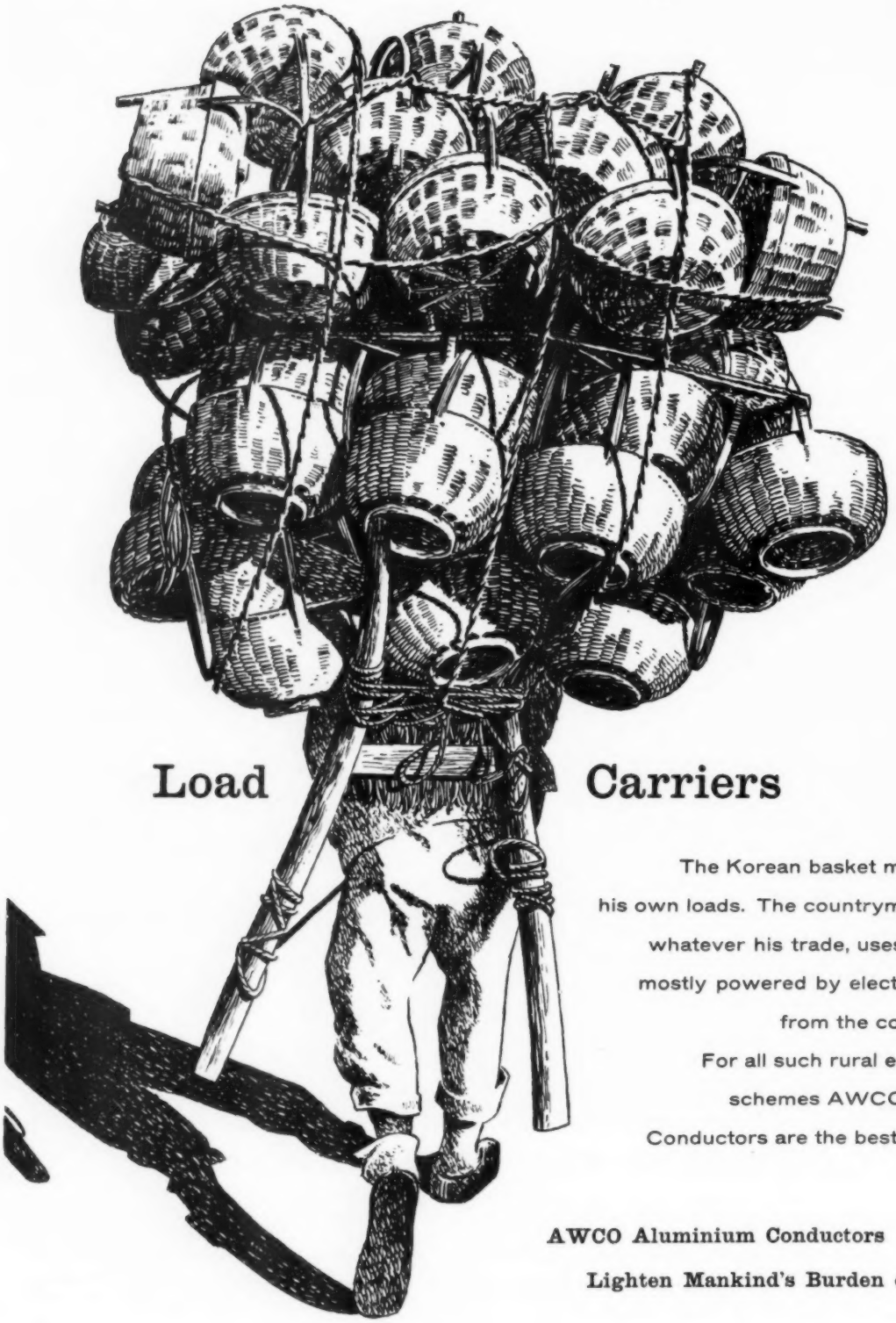

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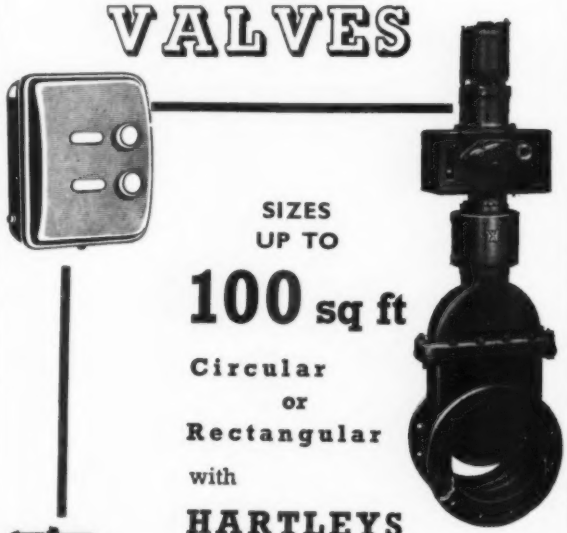

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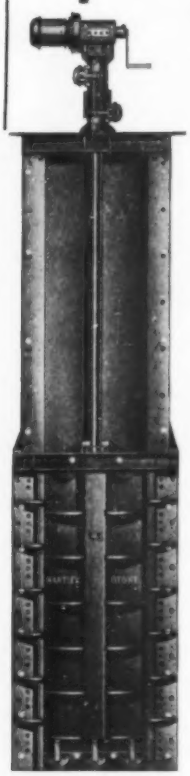

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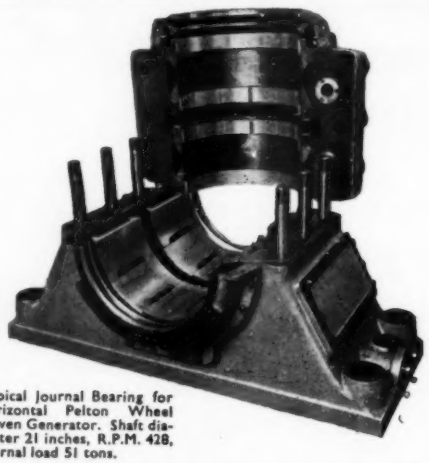

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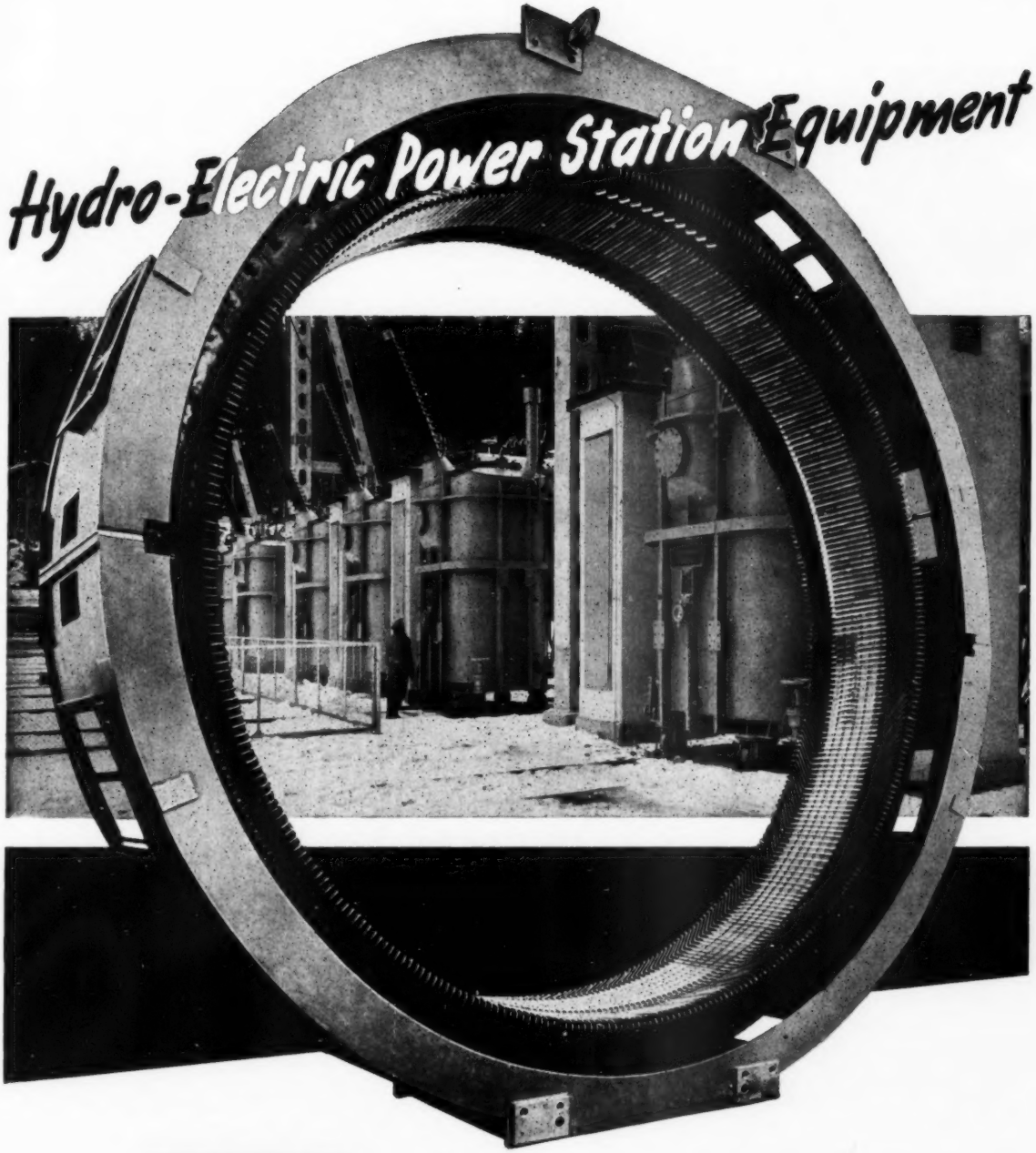

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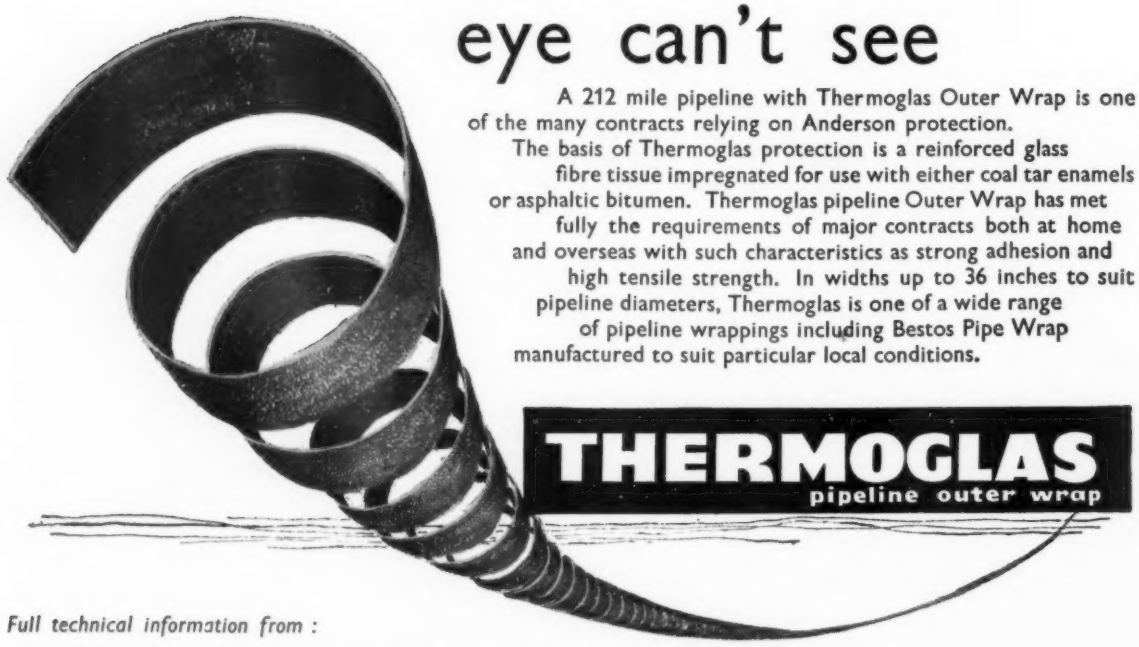

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